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Molecular Transmission Band Models for LOWTRAN

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This report discusses proposed molecular transmittance band models for the uniformly mixed gases (N_2O, CH_4, CO, O_2 and CO_2), the trace gases (NO, NO_2, NH_3 and SO_2), water vapor, and ozone in the infrared. The models are specifically designed for direct incorporation into LOWTRAN 6 atmospheric transmission code.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Molecular Absorption Band Models for LOWTRAN

Summary

This is the final report on a five year effort to develop and validate molecular transmittance band models for the uniformly mixed gases (N_2O, CH_4, CO, O_2 and CO_2), the trace gases (NO, NO_2, NH_3, and SO_2), H_2O vapor and infrared O_3. These models are specifically designed for direct incorporation into a future revision of LOWTRAN 6. The model parameters are provided at 5 cm^{-1} intervals throughout the associated absorption bands, and allow for calculations of 20 cm^{-1} resolution transmittance spectra. The transmission function consists of a simple exponential with the physical variables elevated to some powers, and defined by four parameters, one of which is spectrally dependent. For the most part the models were developed with synthetic spectra, and validated with laboratory measurements. This report presents comparisons between line-by-line calculated spectra and measured laboratory spectra, degraded line-by-line and band model calculated transmittances, and calculations using LOWTRAN 6 and the proposed models. Included are all the model parameters and equations necessary for transmittance calculations along any type of path in the atmospheric environment.

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I. Introduction

In a previous scientific report[1] under this contract the present authors discussed to a large extent the history of the LOWTRAN[2] transmission code, origin and justification for the proposed exponential transmission function[3], numerical methods used in the determination of the model parameters[4], sources of the laboratory measurements, method for generating line-by-line transmittance data using FASCODE[5], and modeling results for the uniformly mixed and the trace gases. All but the last item remained identical in the work that followed that effort, and led to the development of new models for water vapor and ozone. Several meaningful modifications were made to the previously developed models for the uniformly mixed and the trace gases. Hence, this report concentrates on the presentation of primarily the final results for all the molecular absorption band models. A large percentage of these results have already appeared in the open literature[6-12].

The present effort may be best summarized with reference to Tables I and II. Table I shows that the current LOWTRAN 6 model for water vapor extends from 350 to 14520 cm^{-1}, with two gaps inbetween for which calculations are not permissible. Ozone extends continuously from 575 to 3270 cm^{-1} in the infrared region. Likewise, the single model for all the uniformly mixed gases extends from 500 to 13245 cm^{-1}, with a wide spectral gap in between. Table II shows that the water vapor model has been extended continuously from 0 to 17860 cm^{-1}, while ozone has been corrected by eliminating some spectral regions for which calcula-

ABSORBER	SPECTRAL RANGE (CM^{-1})
Water Vapor (H_2O)	350- 9195, 9878-12795, 13400-14520
Ozone (O_3)	575- 3270, 13000-24200, 27500-50000
Uniformly Mixed Gases (CH_4, N_2O, O_2, CO, CO_2)	500- 8070, 12950-13245

Table I. Summary of the Molecular Absorption Band Models In LOWTRAN 6.

ABSORBER	SPECTRAL RANGE (CM^{-1})
Water Vapor (H_2O)	0-17860
Ozone (O_3)	0- 200, 515- 1275, 1630- 2295, 2670-3260, 13000-24200, 27500-50000
Uniformly Mixed Gases:	
Methane (CH_4)	1065- 1775, 2345- 3230, 4110- 4690, 5865- 6135
Nitrous Oxide (N_2O)	0- 120, 490- 775, 865- 995, 1065- 1385, 1545- 2040, 2090- 2655, 2705- 2865, 3245- 3925, 4260- 4470, 4540- 4785, 4910- 5165
Oxygen (O_2)	0- 265, 7650- 8080, 9235- 9490, 12850-13220, 14300-14600, 15695-15955
Carbon Monoxide (CO)	0- 175, 1940- 2285, 4040- 4370
Carbon Dioxide (CO_2)	425- 1440, 1805- 2855, 3070- 4065, 4530- 5380, 5905- 7025, 7395- 7785, 8030- 8335, 9340- 9670
Trace Gases:	
Nitric Oxide (NO)	1700- 2005
Nitrogen Dioxide (NO_2)	580- 925, 1515- 1695, 2800- 2970
Ammonia (NH_3)	0- 2150
Sulphur Dioxide (SO_2)	0- 185, 400- 650, 950- 1460, 2415- 2580

Table II. Summary of the new Molecular Absorption Band Models

tions were unnecessary. The five individual models for the uniformly mixed gases allow for the use of different combinations of absorber concentrations, and extend the spectral coverage from 0 to 15955 cm^{-1}. Finally, Table II shows that models for four trace gases have been included for the calculation of total molecular transmittance, which were nonexistent in LOWTRAN.

II. The Transmission Function

The molecular transmittance τ averaged over a spectral interval $\Delta\nu$ with a triangular instrument response function of 20 cm^{-1} full-width at half intensity, was approximated by the exponential function[3]

$$\tau = \exp\{-(CW)^a\} , \tag{1}$$

where

$$W = (P/Po)^n \; (To/T)^m \; U , \tag{2}$$

$$C = 10 \; C', \tag{3}$$

$$U = 0.7732 \times 10^{-4} \; M\rho_a \; Z \quad \text{for all absorbers, except } H_2O. \tag{4}$$

$$U = 0.1 \; \rho_w Z \quad \text{for } H_2O. \tag{5}$$

In these equations P(atm), T(K), M(ppmv), ρ_w (g/m^3) and ρ_a (g/m^3) are vertical profiles of pressure, temperature, volume mixing ratio, water vapor density, and air density, respectively, U(atm cm) is the absorber amount in Eq. (4), U (g/cm^2) is the absorber amount in Eq. (5), Z(km) is the path length, and the subscript "o" denotes conditions at a standard temperature and pressure (viz. one atm and 273.16 K, respectively). The model is further defined by the absorber parameters set a, n, and m, and by a set of C' values at 5 cm^{-1} spectral intervals. In Eq. (3), C is

redefined in terms of C' for computational convenience. The complete parameter set a, n, m, and C', i = 1,2,...I, for I spectral intervals, was obtained from the equation

$$\varepsilon = \sum_i \sum_j \{\tau(i,j) - \tau_m(i,j)\}^2 \tag{6}$$

where ε is the least-squares error, minimized using the conjugate gradient descent, j = 1,2,...,J is an index for the data values, τ is a transmittance datum, and τ_m is the band model in Eq. (1).

Equation (1) is appealing for use as a transmission function because it is analytically simple and asymptotic to one and zero, respectively, as the argument ranges from zero to infinity. It was used earlier[13] in curve-fitting to the empirical transmission tables in LOWTRAN for water vapor, the uniformly mixed gases, and ozone. More recently, it was adopted in an extensive development effort[1] leading to individual models for the uniformly mixed and trace gases. Although not much physical significance may be attributed to this function, it has been shown[14] that in some cases empirical approximations have outperformed theoretically based band models such as the regular[15] and the random[16]. It does not approach the functional form of any of such classical models in either the limiting weak-line or strong-line conditions (i.e., U/P very small or very large, respectively). It has been shown[3] that it leads to a transmittance polynomial proposed earlier[17] for use with water vapor and carbon dioxide, which, in turn, originated as an approximation to the strong-line limit to the random model. The classical models were derived mostly for homogeneous paths, specific absorption line configurations, and Lorentzian broadening conditions. Equation (1) is generally proposed for

use along inhomogeneous paths, for nonspecific absorption line configurations, and for combinations of Lorentzian and Doppler broadening conditions.

III. Developing Data

The transmittance data used in connection with Eq. (6) in the determination of the complete set of the model parameters, consisted primarily of a combination of laboratory measurements and averaged line-by-line spectra. The line-by-line spectra was generated through calculations with FASCOD1C, which in turn uses standard atmospheric profiles [18] and the AFGL line parameter compilation [19,20]. Details on the calculational process and range of variables representing these data were already covered in the previously cited report [1]. The efforts for H_2O involved laboratory measurements[21,22] which had not been considered in the previous modeling. Table III summarizes the range of all of the transmittance data parameters adopted in the development.

The absorber vertical concentrations for each one of the gases modeled consisted of the profiles proposed by M.S. H. Smith[30], extrapolated so as to match the 33 altitude increments in the standard atmospheric models. After the modeling was completed, each one of the resulting band model was incorporated into LOWTRAN. The latter code was also updated with the new 51-level atmospheric profiles recently generated by AFGL [31]. A composite plot of the concentration profiles for all the absorbers considered in the Tropical Atmosphere is shown in Fig. 1.

RANGE OF MODEL DATA

ABSORBER	SPECTRAL RANGE (CM^{-1})	PRESSURE (ATM) MEAS.	PRESSURE (ATM) CALC.	TEMPERATURE (K) MEAS.	TEMPERATURE (K) CALC.	ABSORBER AMOUNT (ATM CM) MEAS.	ABSORBER AMOUNT (ATM CM) CALC.	REFERENCES FOR MEASURMENTS
Ammonia (NH_3)	0-2150	0.163E+0 to 0.824E+0	0.102E+0 to 1.000E+0	300	217 to 300	0.935E-2 to 0.308E+0	0.962E-2 to 0.316E-1	23
Carbon Dioxide (CO_2)	425-1440 1805-2855 3070-4065 4530-5380 5905-7025 7395-7785 8030-8335 9340-9670	0.100E-1 to 1.000E+0	0.117E-1 to 1.000E+0	216 to 310	217 to 288	0.804E-1 to 0.235E+5	0.856E-2 to 0.300E+5	21,26,27,28
Carbon Monoxide (CO)	0- 175 1940-2285 4040-4370	0.304E+0 to 1.000E+0	0.102E+0 to 1.000E+0	300	230 to 300	0.730E-1 to 0.143E+3	0.350E-1 to 0.275E+3	21
Methane (CH_4)	1065-1775 2345-3230 4110-4690 5865-6135	0.100E+0 to 1.000E+0	0.102E+0 to 1.000E+0	302 to 310	217 to 300	0.922E-1 to 1.375E-1	0.997E-1 to 1.359E+2	21
Nitric Oxide (NO)	1700-2005	0.136E-1 to 0.966E+0	0.546E-1 to 1.000E+0	300	217 to 288	0.722E-1 to 0.310E+0	0.619E-3 to 0.310E+0	24

Table III. Range of Calculated and Measured Transmittance Data Used in the Validation of the Band Models for Molecular Absorption

RANGE OF MODEL DATA

ABSORBER	SPECTRAL RANGE (CM^{-1})	PRESSURE (ATM) MEAS.	PRESSURE (ATM) CALC.	TEMPERATURE (K) MEAS.	TEMPERATURE (K) CALC.	ABSORBER AMOUNT (ATM CM) MEAS.	ABSORBER AMOUNT (ATM CM) CALC.	REFERENCES FOR MEASUREMENTS
Nitrogen Dioxide	580- 925	0.663E-1	0.551E-1	298	217	0.823E-2	0.948E-3	
(NO_2)	1515-1695	to	to	to	to	to	to	22
	2800-2970	1.000E+0	1.000E+0	328	288	0.919E+0	0.119E+0	
Nitrous Oxide	0- 120							
(N_2O)	490- 775							
	865- 995							
	1065-1385							
	1545-2040	0.515E-4	0.102E+0	296	217	0.686E-3	0.962E-3	
	2090-2655	to	to	to	to	to	to	21
	2705-2865	0.484E+0	1.000E+0	301	300	0.387E+3	0.829E+2	
	3245-3925							
	4260-4470							
	4540-4785							
	4910-5165							
Oxygen	0- 265							
(O_2)	7650-8080	0.940E+0	0.102E+0		217	0.274E+4	0.489E+3	
	9235-9490		to	300	to	to	to	25
	12850-13220		1.000E+0		300	0.219E+6	0.256E+9	
	14300-14600							
	15695-15955							
Ozone	0- 200							
(O_3)	515-1275		0.102E+0		217		0.992E-3	
	1630-2295		to	300	to		to	
	2670-3560		1.000E+0		288		0.992E+1	

Table III. Range of Calculated and Measured Transmittance Data Used in the Validation of the Band Models for Molecular Absorption (Continued)

RANGE OF MODEL DATA

ABSORBER	SPECTRAL RANGE (CM^{-1})	PRESSURE (ATM) MEAS.	PRESSURE (ATM) CALC.	TEMPERATURE (K) MEAS.	TEMPERATURE (K) CALC.	ABSORBER AMOUNT (ATM CM) MEAS.	ABSORBER AMOUNT (ATM CM) CALC.	REFERENCES FOR MEASUREMENTS
Sulfur Dioxide (SO_2)	0-185 400-650 950-1460 2415-2580	0.500E-1 to 1.000E+0	0.102E+0 to 1.000E+0	296 to 298	217 to 300	0.186E-1 to 0.584E+1	0.987E-2 to 0.290E+2	29
Water Vapor (H_2O)	0-1000		0.102E+0 to 1.000E+0		217 to 288		0.964E-3 to 0.483E+4	
	1005-16045 16340-17860		0.102E+0 to 1.000E+0		217 to 288		0.254E+3 to 0.255E+6	22

Table III. Range of Calculated and Measured Transmittance Data Used in the Validation of the Band Models for Molecular Absorption (continued)

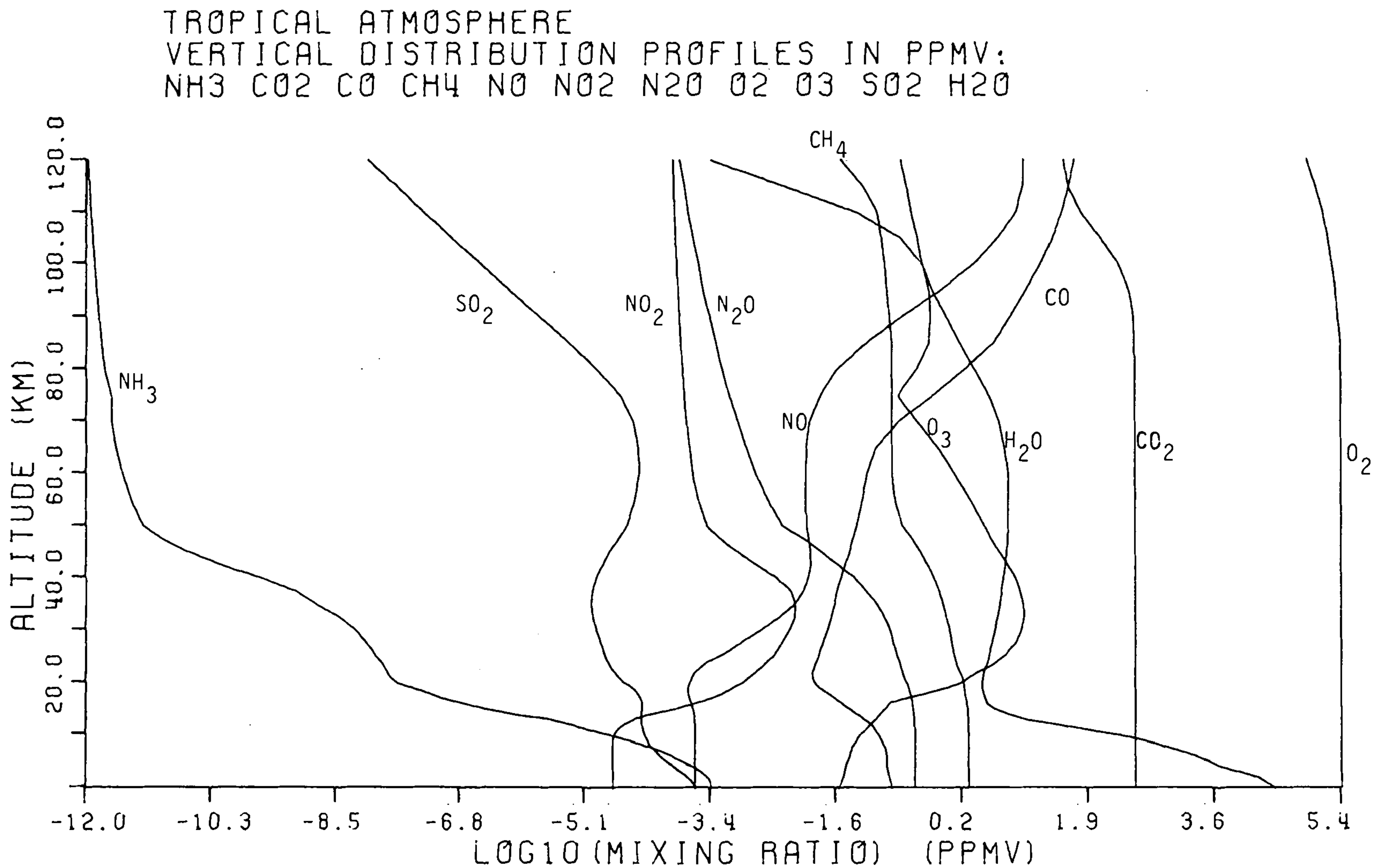

Fig. 1. Vertical Mixing Ratio Profiles for the Absorbers Modeled (Tropical Atmosphere)

IV. Model Development

The numerical procedures discussed briefly in a previous section, and extensively in the earlier cited report, were used with the available data to determine the parameters a, n, m, and C' for the 11 absorbers. In Eqs. (1) through (3) the parameters a, n, m are normally expected to be spectrally independent for a given absorber. The parameter C' is, then, expected to assume all the spectral variability of the band absorption. Although this was the case in general for all the gases having a small number of bands, a few required the use of different sets of parameters throughout the absorption spectrum. Table IV summarizes the results derived from the modeling efforts. The criterion used for deciding on the number of bands to be modeled with a single parameter set, was that the rms transmittance deviation between the model and the modeling data remained below 2 percent. The resulting spectral parameters C' at 5 cm^{-1} intervals are tabulated in Appendix A.

It is worth noting at this point that in the process of determining the band model parameters in the region from zero to 20 cm^{-1}, it was necessary to mimic the lines in this region into the region from zero to -20 cm^{-1}. This allowed for the calculation of mean transmittances at 5 cm^{-1} intervals using a triangular scanning function of 20 cm^{-1} full-width at half intensity on the monochromatic transmittance spectra.

Plots of the transmission functions (i.e. τ versus CW) for each absorber are also of interest when comparing the relative behavior of the different absorbers. Figures (2) through (5) depict the composite transmission functions for the uniformly

ABSORBER	SPECTRAL RANGE (1/CM)	ABSORBER MODEL PARAMETERS A	N	M	RMS ERROR (%)
AMMONIA	0- 385	0.4704	0.8023	-0.9111	1.41
(NH3)	390- 2150	0.6035	0.6968	0.3377	0.76
CARBON	425- 835	0.6176	0.6705	-2.2560	1.84
DIOXIDE	840- 1440	0.6810	0.7038	-5.0768	2.18
(CO2)	1805- 2855	0.6033	0.7258	-1.6740	2.27
	3070- 3755	0.6146	0.6982	-1.8107	1.95
	3760- 4065	0.6513	0.8867	-0.5327	2.49
	4530- 5380	0.6050	0.7883	-1.3244	3.33
	5905- 7025	0.6160	0.6899	-0.8152	1.28
	7395- 7785	0.7070	0.6035	0.6026	0.30
	8030- 8335	0.7070	0.6035	0.6026	0.30
	9340- 9670	0.7070	0.6035	0.6026	0.30
CARBON	0- 175	0.6397	0.7589	0.6911	0.28
MONOXIDE	1940- 2285	0.6133	0.9267	0.1716	0.71
(CO)	4040- 4370	0.6133	0.9267	0.1716	0.71
METHANE	1065- 1775	0.5844	0.7139	-0.4185	1.56
(CH4)	2345- 3230	0.5844	0.7139	-0.4185	1.56
	4110- 4690	0.5844	0.7139	-0.4185	1.56
	5865- 6135	0.5844	0.7139	-0.4185	1.56
NITRIC OXIDE (NO)	1700- 2005	0.6613	0.5265	-0.4702	0.31
NITROGEN	580- 925	0.7249	0.3956	-0.0545	1.49
DIOXIDE	1515- 1695	0.7249	0.3956	-0.0545	1.49
(NO2)	2800- 2970	0.7249	0.3956	-0.0545	1.49
NITROUS	0- 120	0.8997	0.3783	0.9399	0.24
OXIDE	490- 775	0.7201	0.7203	-0.1836	1.49
(N2O)	865- 995	0.7201	0.7203	-0.1836	1.49
	1065- 1385	0.7201	0.7203	-0.1836	1.49
	1545- 2040	0.7201	0.7203	-0.1836	1.49
	2090- 2655	0.7201	0.7203	-0.1836	1.49
	2705- 2865	0.6933	0.7764	1.1931	1.23
	3245- 3925	0.6933	0.7764	1.1931	1.23
	4260- 4470	0.6933	0.7764	1.1931	1.23
	4540- 4785	0.6933	0.7764	1.1931	1.23
	4910- 5165	0.6933	0.7764	1.1931	1.23

Table IV. Summary of Absorber Parameters for the Band Models Developed under the Effort Reported.

ABSORBER	SPECTRAL RANGE (1/CM)	ABSORBER MODEL PARAMETERS A	N	M	RMS ERROR (%)
OXYGEN (O2)	0- 265	0.6011	1.1879	2.9738	1.42
	7650- 8080	0.5641	0.9353	0.1936	0.96
	9235- 9490	0.5641	0.9353	0.1936	0.96
	12850-13220	0.5641	0.9353	0.1936	0.96
	14300-14600	0.5641	0.9353	0.1936	0.96
	15695-15955	0.5641	0.9353	0.1936	0.96
OZONE (O3)	0- 200	0.8559	0.4200	1.3909	1.34
	515- 1275	0.7593	0.4221	0.7678	2.25
	1630- 2295	0.7819	0.3739	0.1225	1.13
	2670- 2845	0.9175	0.1770	0.9827	0.32
	2850- 3260	0.7703	0.3921	0.1942	0.25
SULPHUR DIOXIDE (SO2)	0- 185	0.3907	0.2943	1.2316	1.24
	400- 650	0.8466	0.2135	0.0733	2.38
	950- 1460	0.8466	0.2135	0.0733	2.38
	2415- 2580	0.8466	0.2135	0.0733	2.39
WATER VAPOR (H2O)	0- 345	0.4703	1.0043	0.4502	3.09
	350- 1000	0.5848	0.8642	-3.5479	1.19
	1005- 1640	0.6080	0.7254	-3.9725	1.43
	1645- 2530	0.6412	0.8435	-1.4882	2.93
	2535- 3420	0.7038	0.6820	0.4222	2.30
	3425- 4310	0.6126	0.7862	-0.2278	1.93
	4315- 6150	0.6394	0.7986	-0.4933	2.19
	6155- 8000	0.6296	0.8049	-0.0513	2.01
	8005- 9615	0.6458	0.7805	0.4387	2.39
	9620-11540	0.6485	0.7745	0.7212	1.96
	11545-13070	0.6668	0.7634	0.9759	1.88
	13075-14860	0.7297	0.6368	1.1698	1.82
	14865-16045	0.7630	0.5785	1.2267	0.94
	16340-17860	0.7729	0.5492	1.3681	1.14

Table IV Continued

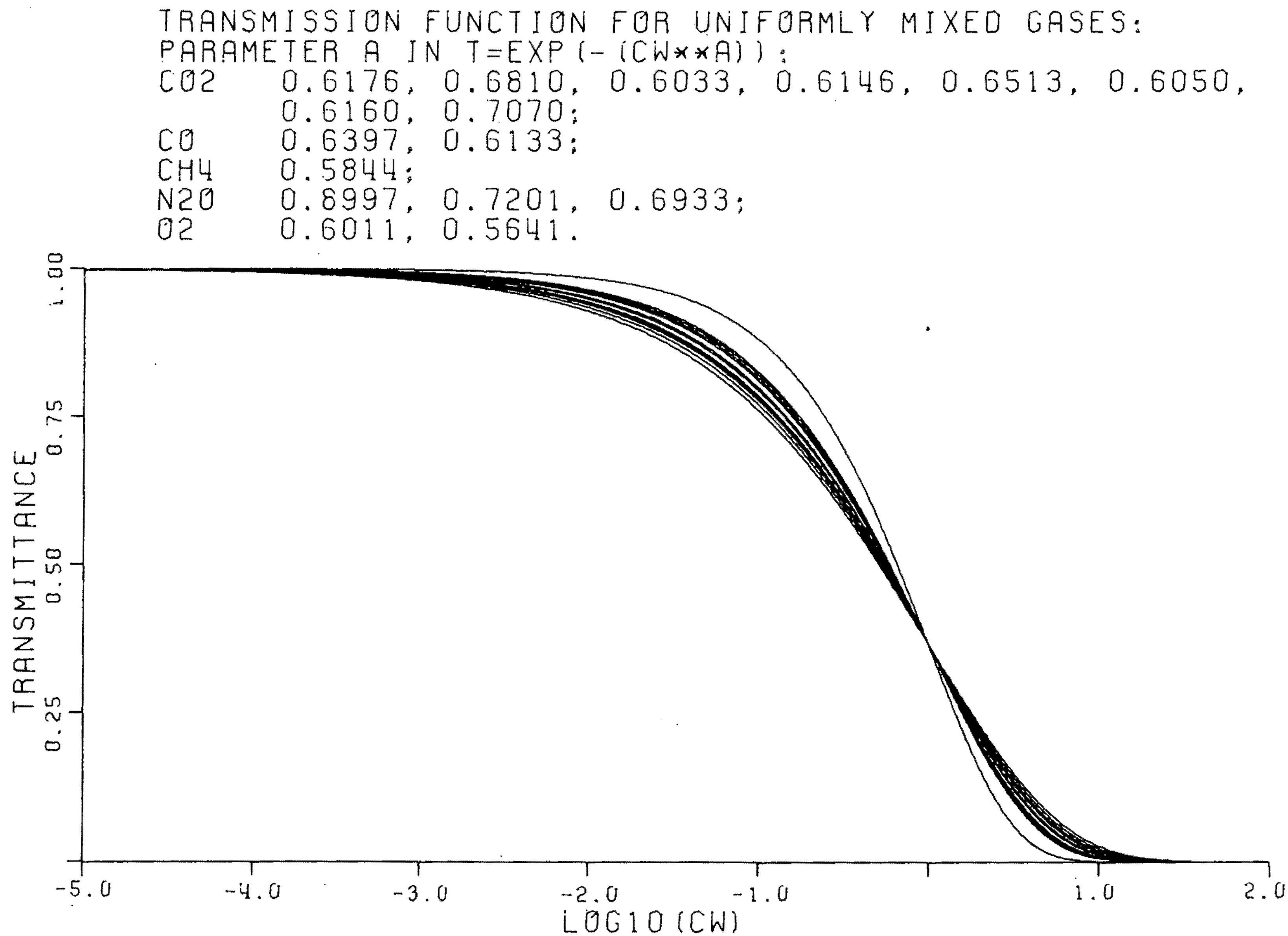

Fig. 2. Composite Plot of the Transmission Functions (Eq. 1) for the Uniformly Mixed Gases

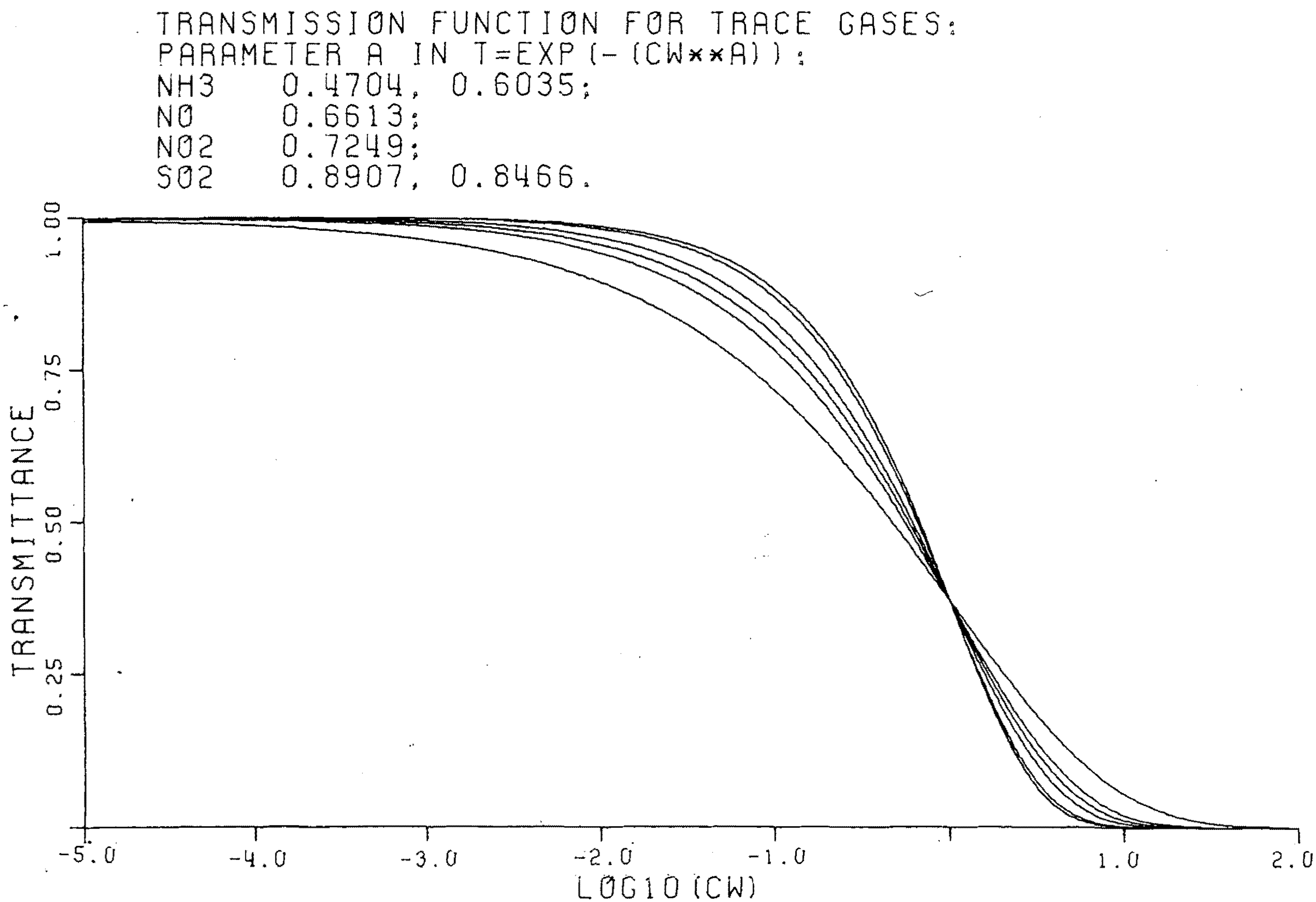

Fig. 3. Composite Plot of the Transmission Functions (Eq. 1) for the Trace Gases

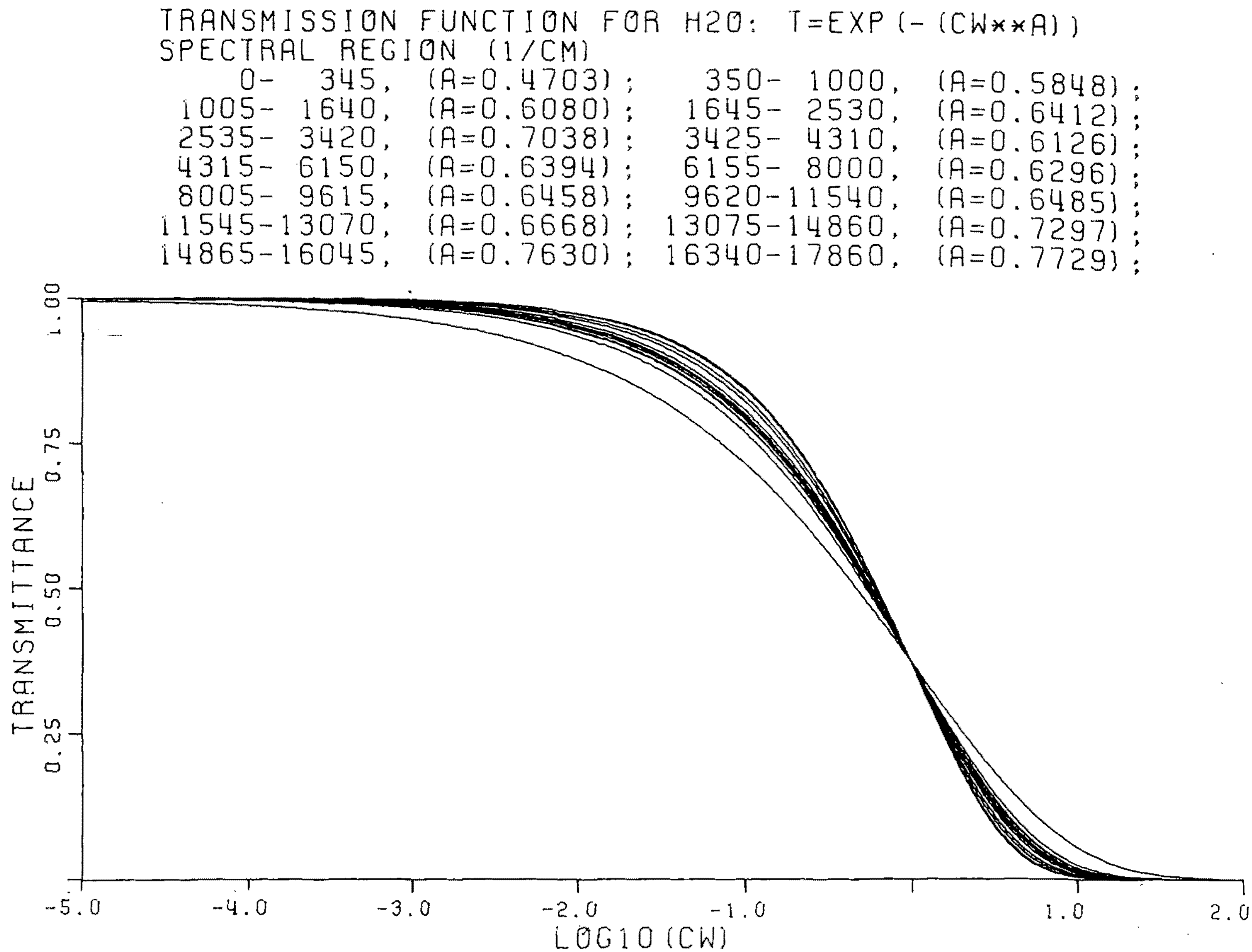

Fig. 4. Composite Plot of the Transmission Functions (Eq. 1) for Water Vapor

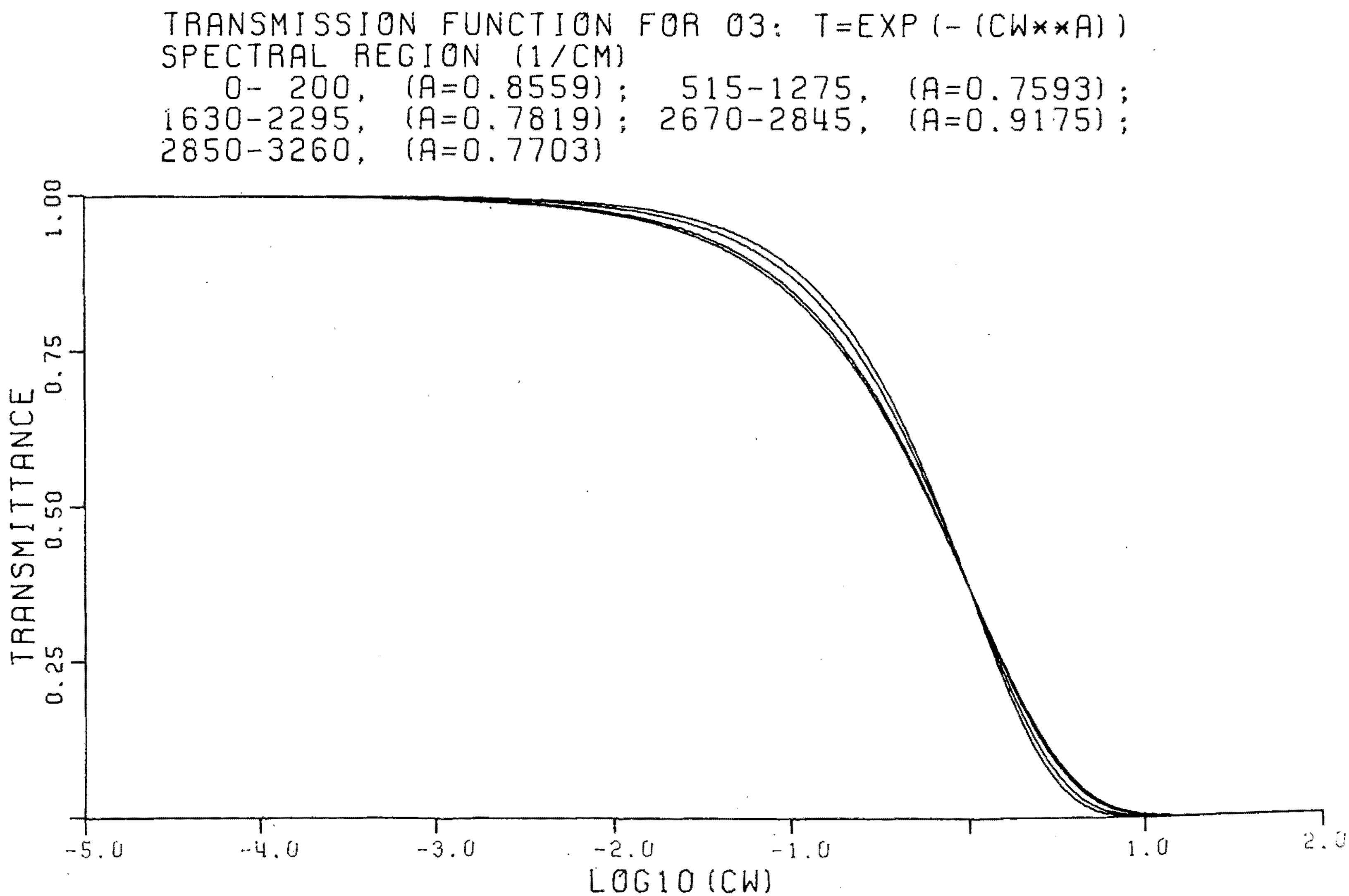

Fig. 5. Composite Plot of the Transmission Functions (Eq. 1) for Ozone

mixed gases, the trace gases, water vapor, and ozone. Plots of the spectral parameter C' for each absorber are included in Appendix B. Individual transmission curves for each model are included in Appendix C.

V. Transmittance Comparisons

Prior to the determination of the model parameters, the line-by-line data were compared with available measurements. Magnetic tapes containing measured spectra for CO_2, CH_4, NO_2, N_2O, SO_2, and H_2O were obtained from AFGL. Only graphical data were available for NH_3, CO, NO, O_2, and O_3. The results of these type of comparisons were already presented in the earlier cited report for all gases except O_3 and H_2O. Graphical comparisons of ozone spectra were made only over a narrow spectral region and, hence, are not worthy of further discussion. However, H_2O comparisons were made over nearly the entire infrared region and were included in two separate reports. Appendix D shows some representative plots of both the nearly monochromatic spectra and of the correspondent degraded values.

Once the spectral comparisons were completed and the band model parameters determined, comparisons were then made between the degraded line-by-line and model calculated transmittances. Appendix E shows typical comparisons for H_2O and O_3, while similar comparisons for the remaining gases may be found in Reference 1. Special calculations were made for several bands for the remaining gases which were modeled after Reference 1 was completed. Such cases included bands in the spectral region from 0 to 350 cm^{-1} of NH_3, CO, N_2O, O_2, O_3, SO_2, and H_2O, as well as

several others primarily in the infrared region. The extent of the remodeling can best be appreciated by examining the summary shown in Table V. Sample comparisons between the degraded line-by-line and band model calculations for the gases absorbing in the region from 0 to 350 cm^{-1} are shown separately in Appendix F.

Upon completion of the modeling of all the absorbing specie, the resulting band models were incorporated into LOWTRAN 6. The primary purpose of this was to be able to ascertain the differences between the existing LOWTRAN models and those being proposed. Figures (6) through (8) show the spectral differences between the transmittances from LOWTRAN and those calculated with the proposed models for the combined uniformly mixed gases, water vapor and ozone, respectively. They are for a path tangent to the earth's surface, extending from one end of the U.S. Standard Atmosphere to the other. They indicate that, in general, transmittance is overestimated in LOWTRAN. This difference may be attributed to inaccuracies in the band models, as well as to absorption bands not modeled in the original LOWTRAN development. More examples of these types of comparisons are shown in Appendix G. Additional transmittance plots for those paths using the proposed band models are included in Appendeix H.

VI. Discussion & Conclusions

The main purpose of the research effort reported here was to develop and validate low-resolution band models from line-by-line calculated transmittance data and laboratory measurements. The gaseous species included in the study were the uniformly mixed gases (N_2O, CH_4, CO, O_2, and CO_2), the trace gases (NO, NO_2, NH_3, and SO_2), H_2O, and O_3. The models were designed for 20 cm^{-1}

Table V. Difference Between Models in Previous Report and Final Versions

ABSORBER	SPECTRAL RANGE (cm^{-1}) REFERENCE 1	THIS REPORT
Ammonia (NH_3)	660-1260	0-385
	1300-1900	390-2150
Carbon Dioxide (CO_2)	425- 850	425-835
	855-1460	840-1440
	1820-2830	1805-2855
	3070-3755	3070-3755
	3760-4105	3760-4065
	4535-5375	4530-5380
	5920-7025	5905-7025
	7395-7820	7395-7785
	8000-8345	8030-8335
		9340-9670
Carbon Monoxide (CO)	1955-2280	0-175
	4055-4365	1940-2285
		4040-4370
Methane (CH_4)	1075-1775	1065-1775
	2370-3230	2345-3230
	4175-4730	4110-4690
		5865-6135
Nitric Oxide (NO)	1700-1995	1700-2005
Nitrogen Dioxide (NO_2)	1540-1670	580-925
	2840-2950	1515-1695
		2800-2970
Nitrous Oxide (N_2O)	500-755	0-120
	1100-1370	490-775
	2105-2630	865-995
		1065-1385
		1545-2040
		2090-2655
		2705-2865
		3245-3925
		4260-4470
		4540-4785
		4910-5165

Table V. (continued)

Oxygen (O_2)	7760-8020 12930-13190	0-265 7650-8080 9235-9490 12850-13220 14300-14600 15695-15955
Ozone (O_3)	(Not Modeled)	0-200 515-1275 1630-2295 2670-3260
Sulphur Dioxide (SO_2)	420-635 1050-1440 2430-2565	0-185 400-650 950-1460 2415-2580
Water Vapor (H_2O)	(Not Modeled)	0-17860

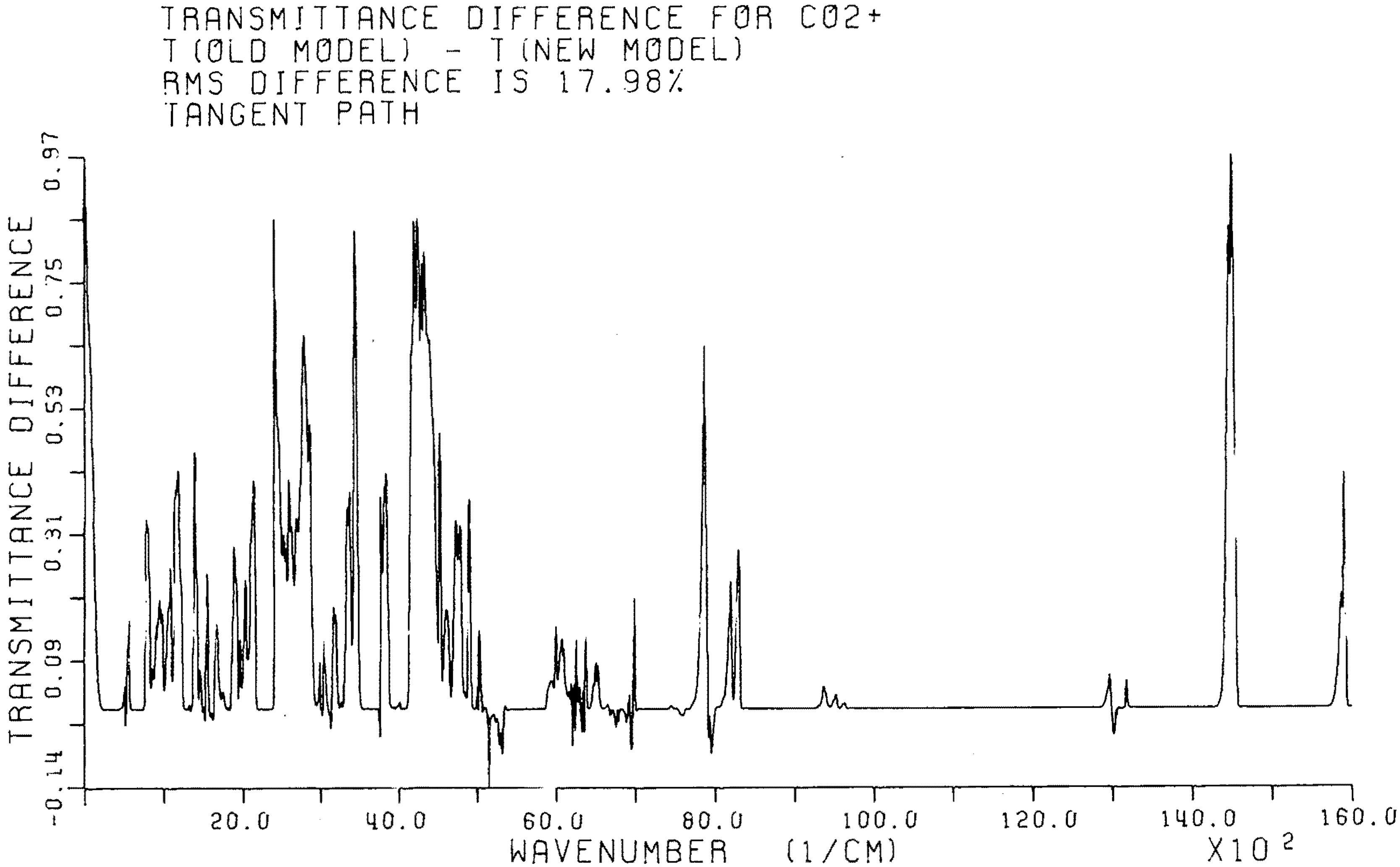

Fig. 6. Transmittance Difference Between LOWTRAN 6 Calculations and the Proposed Models for the Uniformly Mixed Gases Along a Path Tangent to the Earth's Surface in the U.S. Standard Atmosphere.

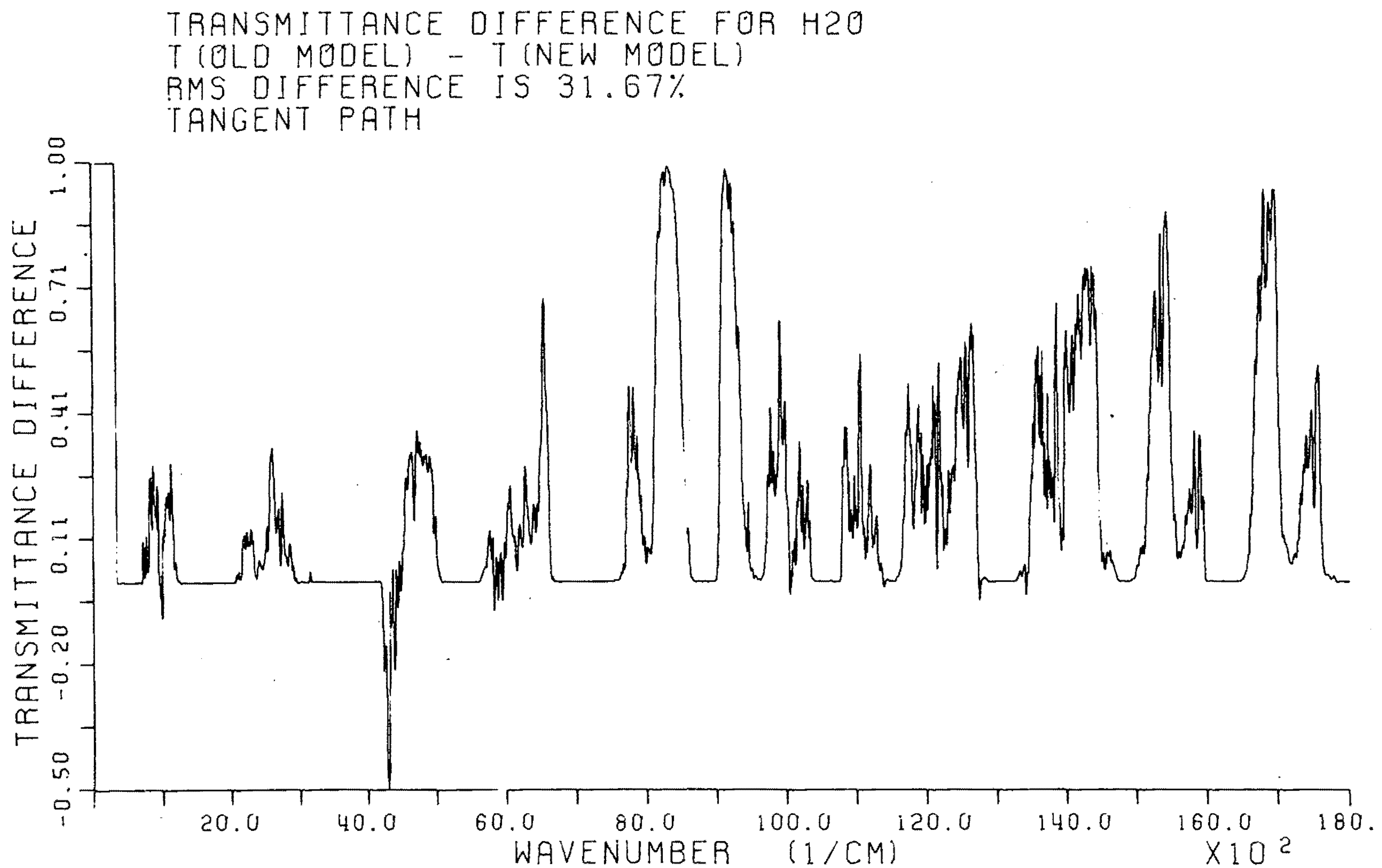

Fig. 7. Transmittance Difference Between LOWTRAN 6 Calculations and the Proposed Model for Water Vapor Along a Path Tangent to the Earth's Surface in the U.S. Standard Atmosphere.

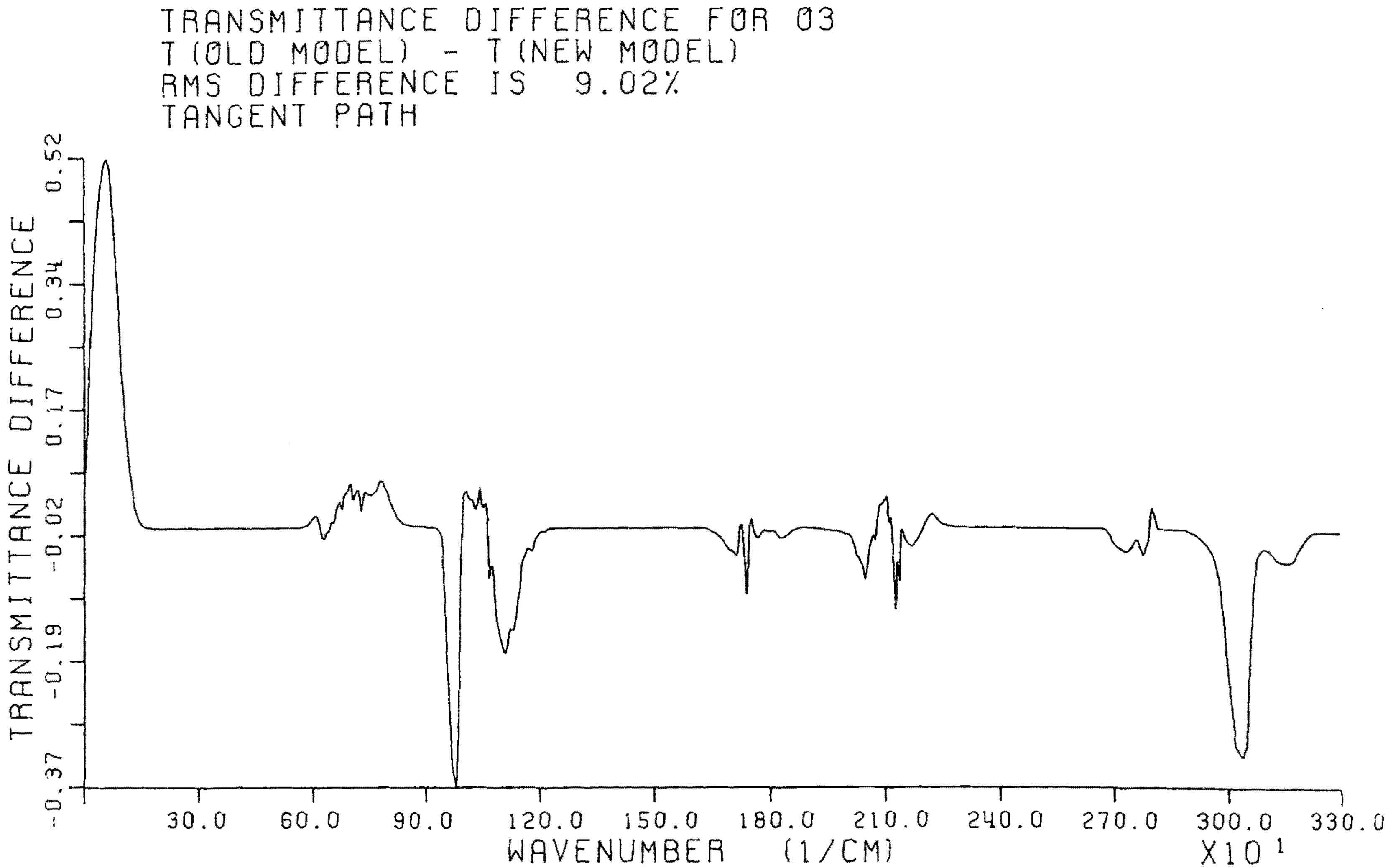

Fig. 8. Transmittance Difference Between LOWTRAN 6 Calculations and the Proposed Model for Ozone Along a Path Tangent to the Earth's Surface in the U.S. Standard Atmosphere.

intervals and the spectral parameters repeated at 5 cm^{-1} for easy incorporation into the latest version of LOWTRAN. The transmission function consisted of an exponential, defined by one spectral and three absorber parameters, representating a simple power relation between the pressure, temperature, and absorber amount along a slant atmospheric path. The determination of the parameters was accomplished through the use of non-linear numerical techniques.

Initially, the available measured data for CO_2, CH_4, NO_2, N_2O, SO_2, and H_2O were compared for accuracy with line-by-line calculations using FASCOD1C. Graphical data in the form of spectral curves were available for comparison for NH_3, CO, NO, O_2, and O_3. Following this form of validation the line-by-line data, and in some cases the transmittance measurements, were used in the determination of all the band model parameters for all the gases of interest. Comparisons were then made between the degraded measurements, the degraded transmittance calculations, and the recalculated transmittances using the resulting band models. The last step in the procedure consisted of incorporating the new models into LOWTRAN 6 and comparing the original LOWTRAN 6 with the modified version.

As a result of all the transmittance comparisons made in the process of the development and validation of the band models for molecular absorption, the following conclusions may be made.

1. The high-resolution transmittance measurements available in magnetic tape form for CO_2, CH_4,

NO_2, N_2O, SO, and H_2O, and in graphical form for NH_3, CO, NO, O_2, and O_3, agreed reasonably well with line-by-line calculations using FASCOD1C.

2. Calculations using the band model parameters determined as a result of the work reported here, agreed within a mean (over all wave-numbers and gases) rms transmittance difference of 2.0% with the degraded line-by-line data used in their determination.

3. Calculations using these proposed band models with the corresponding transmittances computed with LOWTRAN agreed within 2.85% for the uniformly-mixed gases, 16.36% for H_2O and 1.84% for O_3 along a vertical path from sea level to the top of the U.S. Standard Atmosphere.

For the most part it may be concluded that the inclusion of the band models proposed here into LOWTRAN will significantly improve the capabilities of the code to accurately predict molecular transmittance. These improvements will be primarily the result of the use of more accurate band models, better spectral coverage, more recent transmittance data, and the inclusion of additional absorbers for non-standard environments.

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APPENDICES

A. Spectral Parameter C' for NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, O_3, SO_2, and H_2O for use in Equation 1.

B. Spectral Plots of the Parameter C' for NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, O_3, SO_2, and H_2O from Tables in Appendix A.

C. Transmission Functions (τ versus CW) for NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, and SO_2.

D. Comparison Between High Resolution and Degraded Line-By-Line Calculations with Measurements for H_2O.

E. Comparison Between Degraded Line-By-Line and Proposed Model Calculated Transmittance for H_2O and O_3.

F. Comparison Between Degraded Line-By-Line and Proposed Model Calculated Transmittance in the Spectral Region From 0 to 350 cm^{-1} for NH_3, CO, N_2O, O_2, O_3, SO_2, and H_2O.

G. Comparison Between LOWTRAN and Proposed Model Transmittance Calculations for the Uniformly Mixed Gases (N_2O, CH_4, CO, O_2, and CO_2 combined), H_2O, and O_3.

H. Transmittance Through NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, O_3, SO_2, and H_2O in the U.S. Standard Atmosphere Along Atmospheric Paths Discussed in Texts.

I. Papers published under this contractual effort.

APPENDIX A

Spectral Parameter C' for NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, O_3, SO_2, and H_2O for use in Equation 1.

TABLE A1

C' VALUE FOR NH3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-5.7142	240	-1.4920	480	-4.3961	720	-2.4372
5	-5.2854	245	-1.5403	485	-4.2607	725	-2.3085
10	-4.5163	250	-1.5848	490	-4.1705	730	-2.1696
15	-3.9795	255	-1.6498	495	-4.1294	735	-2.0302
20	-3.4393	260	-1.7382	500	-4.0611	740	-1.9166
25	-2.8735	265	-1.8294	505	-3.9538	745	-1.8071
30	-2.4947	270	-1.9203	510	-3.8821	750	-1.7221
35	-2.2290	275	-2.0694	515	-3.7592	755	-1.6370
40	-2.0624	280	-2.2134	520	-3.6754	760	-1.5453
45	-1.9616	285	-2.3622	525	-3.6830	765	-1.4487
50	-1.8707	290	-2.5516	530	-3.6977	770	-1.3539
55	-1.7712	295	-2.7633	535	-3.6925	775	-1.2570
60	-1.6473	300	-2.9344	540	-3.6632	780	-1.1618
65	-1.5376	305	-3.1172	545	-3.5899	785	-1.1131
70	-1.4315	310	-3.3543	550	-3.5218	790	-1.0824
75	-1.3328	315	-3.5671	555	-3.5265	795	-1.0559
80	-1.2391	320	-3.7504	560	-3.6535	800	-1.0190
85	-1.1768	325	-3.9884	565	-3.8068	805	-0.9721
90	-1.1302	330	-4.2633	570	-3.9818	810	-0.9218
95	-1.0755	335	-4.5505	575	-4.0574	815	-0.8680
100	-1.0272	340	-4.7837	580	-3.9789	820	-0.8556
105	-0.9884	345	-5.0350	585	-3.8358	825	-0.8568
110	-0.9501	350	-5.3733	590	-3.8120	830	-0.8713
115	-0.9287	355	-5.6478	595	-3.8927	835	-0.8984
120	-0.9101	360	-5.8856	600	-3.8799	840	-0.9076
125	-0.8982	365	-6.1041	605	-3.8623	845	-0.9024
130	-0.8888	370	-6.3375	610	-3.3984	850	-0.8882
135	-0.8709	375	-6.5709	615	-2.8857	855	-0.8968
140	-0.8620	380	-6.8043	620	-2.5814	860	-0.9492
145	-0.8645	385	-7.0377	625	-2.4066	865	-1.0089
150	-0.8676	390	-7.2620	630	-2.3850	870	-1.0846
155	-0.8910	395	-7.0950	635	-2.5415	875	-1.1556
160	-0.9084	400	-6.9279	640	-2.8161	880	-1.1792
165	-0.9328	405	-6.7608	645	-3.2265	885	-1.1946
170	-0.9546	410	-6.5938	650	-3.7177	890	-1.1964
175	-0.9743	415	-6.4267	655	-3.9932	895	-1.2173
180	-0.9983	420	-6.2597	660	-4.0683	900	-1.2424
185	-1.0202	425	-6.0926	665	-4.0785	905	-1.1744
190	-1.0569	430	-5.8842	670	-3.9912	910	-0.9743
195	-1.0824	435	-5.7560	675	-3.7418	915	-0.6350
200	-1.1086	440	-5.5844	680	-3.4742	920	-0.2975
205	-1.1475	445	-5.4248	685	-3.2651	925	-0.0705
210	-1.1790	450	-5.2573	690	-3.0715	930	0.0144
215	-1.2059	455	-5.0771	695	-2.9500	935	-0.0978
220	-1.2668	460	-4.9244	700	-2.8669	940	-0.3536
225	-1.3237	465	-4.7903	705	-2.7723	945	-0.5630
230	-1.3801	470	-4.6512	710	-2.6614	950	-0.5479
235	-1.4271	475	-4.5169	715	-2.5613	955	-0.3784

C' VALUE FOR NH3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
960	-0.1797	1200	-2.3724	1440	-3.0384	1680	-1.2949
965	-0.1151	1205	-2.4917	1445	-2.9243	1685	-1.2708
970	-0.3085	1210	-2.6218	1450	-2.7755	1690	-1.1896
975	-0.6180	1215	-2.8056	1455	-2.5809	1695	-1.1467
980	-0.9718	1220	-2.9693	1460	-2.4726	1700	-1.1187
985	-1.2926	1225	-3.1101	1465	-2.3206	1705	-1.0700
990	-1.2748	1230	-3.2790	1470	-2.1209	1710	-1.0392
995	-1.1217	1235	-3.5315	1475	-2.0331	1715	-1.0227
1000	-1.0197	1240	-3.7011	1480	-1.9016	1720	-1.0178
1005	-0.9300	1245	-3.8952	1485	-1.7458	1725	-1.0089
1010	-0.8817	1250	-4.1527	1490	-1.6927	1730	-1.0021
1015	-0.8723	1255	-4.4121	1495	-1.5958	1735	-0.9706
1020	-0.8309	1260	-4.5244	1500	-1.4863	1740	-0.9569
1025	-0.7804	1265	-4.8599	1505	-1.4492	1745	-0.9928
1030	-0.7075	1270	-5.1940	1510	-1.3730	1750	-1.0310
1035	-0.6431	1275	-5.5589	1515	-1.2859	1755	-1.0767
1040	-0.6176	1280	-5.8170	1520	-1.2554	1760	-1.1053
1045	-0.6012	1285	-6.1402	1525	-1.2129	1765	-1.1241
1050	-0.6079	1290	-6.4633	1530	-1.1689	1770	-1.1717
1055	-0.6272	1295	-6.7865	1535	-1.1802	1775	-1.2203
1060	-0.6304	1300	-7.1096	1540	-1.1948	1780	-1.2772
1065	-0.6193	1305	-7.4328	1545	-1.1882	1785	-1.3356
1070	-0.6026	1310	-7.7559	1550	-1.2185	1790	-1.3855
1075	-0.5882	1315	-8.0000	1555	-1.2464	1795	-1.4734
1080	-0.6029	1320	-7.8199	1560	-1.2522	1800	-1.5701
1085	-0.6317	1325	-7.5988	1565	-1.2946	1805	-1.6572
1090	-0.6862	1330	-7.3778	1570	-1.3587	1810	-1.7639
1095	-0.7447	1335	-7.1567	1575	-1.3971	1815	-1.8652
1100	-0.7921	1340	-6.9357	1580	-1.4488	1820	-1.9918
1105	-0.8275	1345	-6.7146	1585	-1.5261	1825	-2.1449
1110	-0.8595	1350	-6.4936	1590	-1.5495	1830	-2.2388
1115	-0.8856	1355	-6.2725	1595	-1.5478	1835	-2.3251
1120	-0.9236	1360	-6.0515	1600	-1.4926	1840	-2.3936
1125	-0.9934	1365	-5.8304	1605	-1.3115	1845	-2.4525
1130	-1.0693	1370	-5.5963	1610	-1.0455	1850	-2.5998
1135	-1.1460	1375	-5.3883	1615	-0.7987	1855	-2.7147
1140	-1.2100	1380	-5.2319	1620	-0.5972	1860	-2.7704
1145	-1.2863	1385	-5.0536	1625	-0.4664	1865	-2.7852
1150	-1.3593	1390	-4.9029	1630	-0.4244	1870	-2.7524
1155	-1.4292	1395	-4.7789	1635	-0.4426	1875	-2.7646
1160	-1.5029	1400	-4.5867	1640	-0.4952	1880	-2.8507
1165	-1.6054	1405	-4.3414	1645	-0.5772	1885	-3.0422
1170	-1.7067	1410	-4.1399	1650	-0.6845	1890	-3.2642
1175	-1.8110	1415	-3.9784	1655	-0.8097	1895	-3.5201
1180	-1.9350	1420	-3.7553	1660	-0.9443	1900	-3.6328
1185	-2.0346	1425	-3.5773	1665	-1.0904	1905	-3.7624
1190	-2.1305	1430	-3.4123	1670	-1.2232	1910	-3.9505
1195	-2.2294	1435	-3.2254	1675	-1.2853	1915	-4.1399

C' VALUE FOR NH3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1920	-4.3087	1980	-4.0997	2040	-4.8370	2100	-6.5415
1925	-4.3859	1985	-4.0659	2045	-5.0041	2105	-6.6886
1930	-4.4295	1990	-4.0264	2050	-5.1644	2110	-6.8358
1935	-4.4493	1995	-4.0893	2055	-5.2101	2115	-6.9829
1940	-4.3317	2000	-4.1832	2060	-5.4145	2120	-7.1301
1945	-4.1892	2005	-4.2522	2065	-5.5114	2125	-7.2772
1950	-4.0545	2010	-4.3182	2070	-5.6986	2130	-7.4244
1955	-3.9356	2015	-4.3949	2075	-5.8057	2135	-7.5715
1960	-3.9117	2020	-4.4191	2080	-5.9529	2140	-7.7187
1965	-4.0001	2025	-4.4580	2085	-6.1000	2145	-7.8658
1970	-4.0627	2030	-4.5997	2090	-6.2472	2150	-8.0000
1975	-4.0833	2035	-4.7282	2095	-6.3943		

TABLE A2

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
425	-9.8495	665	0.1114	905	-5.2028	1145	-9.1413
430	-9.6484	670	0.1367	910	-5.0799	1150	-9.1221
435	-9.4472	675	0.0910	915	-4.9628	1155	-9.1882
440	-9.2461	680	0.0066	920	-4.8379	1160	-9.2752
445	-9.0449	685	-0.1269	925	-4.7032	1165	-9.2237
450	-8.9544	690	-0.2994	930	-4.5584	1170	-9.3604
455	-8.6127	695	-0.4934	935	-4.4213	1175	-9.3058
460	-8.4076	700	-0.7101	940	-4.3198	1180	-9.5455
465	-8.2710	705	-0.9087	945	-4.2786	1185	-9.5567
470	-8.0391	710	-1.1004	950	-4.2843	1190	-9.3754
475	-7.9485	715	-1.2694	955	-4.3099	1195	-8.7756
480	-7.9638	720	-1.4064	960	-4.3210	1200	-8.0904
485	-7.7849	725	-1.5622	965	-4.2769	1205	-7.4827
490	-7.6278	730	-1.6810	970	-4.2229	1210	-6.9585
495	-7.1418	735	-1.7841	975	-4.2179	1215	-6.5095
500	-6.7823	740	-1.8973	980	-4.2950	1220	-6.1194
505	-6.3826	745	-2.0274	985	-4.4789	1225	-5.7824
510	-6.0323	750	-2.2079	990	-4.7550	1230	-5.4910
515	-5.7501	755	-2.4264	995	-5.0902	1235	-5.2532
520	-5.5249	760	-2.6763	1000	-5.4329	1240	-5.0840
525	-5.3304	765	-2.9312	1005	-5.6689	1245	-4.9920
530	-5.0105	770	-3.1896	1010	-5.6608	1250	-4.9577
535	-4.7703	775	-3.4262	1015	-5.4582	1255	-4.9638
540	-4.5714	780	-3.5979	1020	-5.1969	1260	-4.9741
545	-4.3919	785	-3.7051	1025	-4.9419	1265	-4.9555
550	-4.2974	790	-3.7372	1030	-4.7106	1270	-4.9466
555	-4.1370	795	-3.7983	1035	-4.5084	1275	-4.9774
560	-3.8761	800	-3.9154	1040	-4.3409	1280	-5.0719
565	-3.5936	805	-4.0520	1045	-4.2211	1285	-5.2558
570	-3.2852	810	-4.2567	1050	-4.1563	1290	-5.5213
575	-3.0016	815	-4.4661	1055	-4.1259	1295	-5.8633
580	-2.7303	820	-4.6670	1060	-4.1108	1300	-6.2877
585	-2.4868	825	-4.9226	1065	-4.0803	1305	-6.7878
590	-2.2741	830	-5.2203	1070	-4.0211	1310	-7.2602
595	-2.0936	835	-5.5597	1075	-3.9824	1315	-7.2940
600	-1.9424	840	-5.6403	1080	-4.0053	1320	-6.8524
605	-1.8092	845	-5.7039	1085	-4.1221	1325	-6.3372
610	-1.6843	850	-5.7674	1090	-4.3504	1330	-5.8854
615	-1.5372	855	-5.8310	1095	-4.6741	1335	-5.5065
620	-1.3803	860	-5.8948	1100	-5.0826	1340	-5.2011
625	-1.2043	865	-5.9503	1105	-5.5857	1345	-4.9776
630	-0.9930	870	-6.0217	1110	-6.2301	1350	-4.8471
635	-0.7724	875	-6.0392	1115	-7.0829	1355	-4.7885
640	-0.5509	880	-5.9855	1120	-8.1344	1360	-4.7783
645	-0.3465	885	-5.8620	1125	-8.8601	1365	-4.7815
650	-0.1785	890	-5.6834	1130	-9.0457	1370	-4.7538
655	-0.0470	895	-5.5083	1135	-9.1231	1375	-4.7228
660	0.0449	900	-5.3473	1140	-9.0728	1380	-4.7259

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1385	-4.7860	1985	-5.8862	2225	-2.6127	2465	-4.3369
1390	-4.9231	1990	-6.0581	2230	-2.3212	2470	-4.4329
1395	-5.1270	1995	-6.0274	2235	-2.0435	2475	-4.5305
1400	-5.3831	2000	-5.8356	2240	-1.7894	2480	-4.6264
1405	-5.6849	2005	-5.5989	2245	-1.5531	2485	-4.7438
1410	-6.0351	2010	-5.3738	2250	-1.3382	2490	-4.8842
1415	-6.4437	2015	-5.1661	2255	-1.1515	2495	-5.0248
1420	-6.9160	2020	-4.9472	2260	-0.9990	2500	-5.1448
1425	-7.4815	2025	-4.7020	2265	-0.8833	2505	-5.2371
1430	-8.1437	2030	-4.4354	2270	-0.8006	2510	-5.2781
1435	-8.9449	2035	-4.1439	2275	-0.7227	2515	-5.3299
1440	-9.8564	2040	-3.8561	2280	-0.6288	2520	-5.3766
1805	-9.8903	2045	-3.5944	2285	-0.4977	2525	-5.4233
1810	-9.4365	2050	-3.3694	2290	-0.3249	2530	-5.4699
1815	-8.9826	2055	-3.2100	2295	-0.1349	2535	-5.5166
1820	-8.5288	2060	-3.1041	2300	0.0576	2540	-5.5633
1825	-8.1184	2065	-3.0411	2305	0.2487	2545	-5.6646
1830	-7.6555	2070	-3.0471	2310	0.4386	2550	-5.7593
1835	-7.1673	2075	-3.1077	2315	0.6260	2555	-5.8461
1840	-6.7226	2080	-3.2305	2320	0.8081	2560	-5.9229
1845	-6.3423	2085	-3.4274	2325	0.9681	2565	-5.9818
1850	-6.0410	2090	-3.6115	2330	1.0859	2570	-6.0065
1855	-5.8154	2095	-3.7542	2335	1.1522	2575	-5.9747
1860	-5.6519	2100	-3.8666	2340	1.1861	2580	-5.8741
1865	-5.5186	2105	-3.9338	2345	1.2039	2585	-5.7230
1870	-5.3859	2110	-4.0079	2350	1.2255	2590	-5.5620
1875	-5.2279	2115	-4.0962	2355	1.2587	2595	-5.4389
1880	-5.0238	2120	-4.2142	2360	1.2473	2600	-5.3788
1885	-4.7865	2125	-4.1433	2365	1.1457	2605	-5.3679
1890	-4.5343	2130	-4.2870	2370	0.9139	2610	-5.3827
1895	-4.2846	2135	-4.4796	2375	0.5250	2615	-5.3837
1900	-4.0560	2140	-4.6618	2380	0.0173	2620	-5.3460
1905	-3.8717	2145	-4.8204	2385	-0.5796	2625	-5.3186
1910	-3.7624	2150	-4.9499	2390	-1.3944	2630	-5.3394
1915	-3.7231	2155	-4.9862	2395	-2.3841	2635	-5.4320
1920	-3.7335	2160	-5.0171	2400	-2.7244	2640	-5.6095
1925	-3.8312	2165	-5.0282	2405	-2.9264	2645	-5.8446
1930	-3.9854	2170	-5.0580	2410	-3.0689	2650	-6.0992
1935	-4.1930	2175	-5.0398	2415	-3.2120	2655	-6.3399
1940	-4.4895	2180	-4.9465	2420	-3.3353	2660	-6.5499
1945	-4.7394	2185	-4.7816	2425	-3.4510	2665	-6.7434
1950	-4.8892	2190	-4.5538	2430	-3.5566	2670	-6.9359
1955	-4.9499	2195	-4.2975	2435	-3.6518	2675	-7.1219
1960	-4.9392	2200	-4.0286	2440	-3.7460	2680	-7.2818
1965	-4.9787	2205	-3.7528	2445	-3.8500	2685	-7.3984
1970	-5.1129	2210	-3.4715	2450	-3.9680	2690	-7.4881
1975	-5.3330	2215	-3.1899	2455	-4.0981	2695	-7.5452
1980	-5.6093	2220	-2.9041	2460	-4.2259	2700	-7.5994

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2705	-7.6445	3155	-5.9088	3395	-6.6681	3635	-0.9908
2710	-7.6734	3160	-5.8590	3400	-6.9127	3640	-1.2503
2715	-7.6422	3165	-5.8890	3405	-6.8919	3645	-1.5347
2720	-7.5057	3170	-5.9850	3410	-6.6972	3650	-1.7934
2725	-7.2650	3175	-6.0949	3415	-6.5012	3655	-1.9837
2730	-6.9975	3180	-6.1164	3420	-6.3123	3660	-2.0715
2735	-6.7749	3185	-6.0207	3425	-6.1091	3665	-2.0375
2740	-6.6398	3190	-5.8592	3430	-5.8641	3670	-1.8975
2745	-6.5875	3195	-5.7110	3435	-5.5889	3675	-1.6906
2750	-6.5912	3200	-5.6328	3440	-5.3057	3680	-1.4497
2755	-6.6192	3205	-5.6369	3445	-5.0340	3685	-1.2048
2760	-6.6155	3210	-5.7274	3450	-4.7826	3690	-0.9831
2765	-6.5866	3215	-5.9069	3455	-4.5476	3695	-0.8125
2770	-6.5851	3220	-6.1720	3460	-4.3277	3700	-0.7157
2775	-6.6382	3225	-6.5203	3465	-4.1224	3705	-0.6707
2780	-6.7736	3230	-6.9586	3470	-3.9333	3710	-0.6532
2785	-7.0009	3235	-7.4776	3475	-3.7675	3715	-0.6297
2790	-7.2896	3240	-8.0607	3480	-3.6324	3720	-0.5706
2795	-7.6327	3245	-8.5514	3485	-3.5163	3725	-0.5263
2800	-7.9767	3250	-8.7011	3490	-3.4043	3730	-0.5489
2805	-8.2633	3255	-8.4232	3495	-3.2744	3735	-0.6857
2810	-8.4744	3260	-7.9274	3500	-3.1180	3740	-0.9793
2815	-8.5455	3265	-7.6159	3505	-2.9557	3745	-1.3962
2820	-8.5813	3270	-7.3836	3510	-2.8254	3750	-1.8673
2825	-8.6025	3275	-7.1969	3515	-2.7359	3755	-2.3655
2830	-8.6459	3280	-7.0523	3520	-2.6721	3760	-3.5436
2835	-8.8948	3285	-6.7685	3525	-2.6084	3765	-4.0424
2840	-9.1436	3290	-6.4022	3530	-2.5105	3770	-4.4084
2845	-9.3925	3295	-6.0354	3535	-2.3772	3775	-4.6848
2850	-9.6413	3300	-5.7125	3540	-2.2317	3780	-4.8663
2855	-9.8902	3305	-5.4659	3545	-2.0866	3785	-4.9516
3070	-9.8006	3310	-5.3088	3550	-1.9521	3790	-4.9790
3075	-9.5049	3315	-5.2546	3555	-1.8292	3795	-4.9923
3080	-9.1947	3320	-5.2991	3560	-1.7110	3800	-5.0297
3085	-8.7254	3325	-5.3819	3565	-1.5992	3805	-5.0596
3090	-8.4410	3330	-5.4615	3570	-1.4873	3810	-5.0958
3095	-8.1781	3335	-5.4117	3575	-1.3646	3815	-5.1018
3100	-8.0182	3340	-5.2107	3580	-1.2260	3820	-5.0636
3105	-7.9381	3345	-5.0103	3585	-1.0721	3825	-5.0354
3110	-7.8793	3350	-4.8232	3590	-0.9281	3830	-5.0546
3115	-7.7636	3355	-4.7071	3595	-0.8379	3835	-5.1454
3120	-7.5549	3360	-4.6850	3600	-0.8123	3840	-5.3274
3125	-7.2962	3365	-4.7385	3605	-0.8261	3845	-5.5863
3130	-7.0244	3370	-4.8797	3610	-0.8483	3850	-5.8389
3135	-6.7556	3375	-5.1024	3615	-0.8305	3855	-6.1770
3140	-6.4888	3380	-5.4015	3620	-0.7792	3860	-6.3555
3145	-6.2443	3385	-5.7758	3625	-0.7626	3865	-6.4096
3150	-6.0422	3390	-6.2225	3630	-0.8228	3870	-6.4371

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
3875	-6.5112	4575	-7.5942	4815	-3.4912	5055	-4.0891
3880	-6.6680	4580	-7.5256	4820	-3.3444	5060	-3.8565
3885	-6.9183	4585	-7.3190	4825	-3.1983	5065	-3.6218
3890	-7.2418	4590	-6.9986	4830	-3.0732	5070	-3.3909
3895	-7.5827	4595	-6.6884	4835	-3.0262	5075	-3.1785
3900	-7.8704	4600	-6.4102	4840	-3.0078	5080	-3.0100
3905	-8.0551	4605	-6.1769	4845	-3.0123	5085	-2.9105
3910	-8.1705	4610	-5.9882	4850	-3.0213	5090	-2.8588
3915	-8.2500	4615	-5.8421	4855	-2.9957	5095	-2.8286
3920	-8.3554	4620	-5.7499	4860	-2.9261	5100	-2.7912
3925	-8.3961	4625	-5.7201	4865	-2.8770	5105	-2.7207
3930	-8.4354	4630	-5.7189	4870	-2.8887	5110	-2.6729
3935	-8.3920	4635	-5.7108	4875	-2.9853	5115	-2.6858
3940	-8.2785	4640	-5.6669	4880	-3.1609	5120	-2.7745
3945	-8.0499	4645	-5.5955	4885	-3.3643	5125	-2.9414
3950	-7.7437	4650	-5.5686	4890	-3.5468	5130	-3.1445
3955	-7.4130	4655	-5.6287	4895	-3.6759	5135	-3.3617
3960	-7.1153	4660	-5.8000	4900	-3.7488	5140	-3.5954
3965	-6.8861	4665	-6.0355	4905	-3.7704	5145	-3.8508
3970	-6.7422	4670	-6.4398	4910	-3.7535	5150	-4.1739
3975	-6.6786	4675	-6.7793	4915	-3.7113	5155	-4.5122
3980	-6.6774	4680	-6.9427	4920	-3.6368	5160	-4.8985
3985	-6.7053	4685	-6.9205	4925	-3.5277	5165	-5.3426
3990	-6.7090	4690	-6.8363	4930	-3.3812	5170	-5.8737
3995	-6.6794	4695	-6.7059	4935	-3.2020	5175	-6.4734
4000	-6.6055	4700	-6.5272	4940	-3.0043	5180	-7.0715
4005	-6.4827	4705	-6.2903	4945	-2.8020	5185	-7.5042
4010	-6.3454	4710	-6.0085	4950	-2.6122	5190	-7.6034
4015	-6.2401	4715	-5.7224	4955	-2.4524	5195	-7.5143
4020	-6.1992	4720	-5.4722	4960	-2.3405	5200	-7.4358
4025	-6.2676	4725	-5.2772	4965	-2.2838	5205	-7.4089
4030	-6.4833	4730	-5.1501	4970	-2.2521	5210	-7.3969
4035	-6.8490	4735	-5.0768	4975	-2.2319	5215	-7.3813
4040	-7.4310	4740	-5.0219	4980	-2.1960	5220	-7.3018
4045	-8.4606	4745	-4.9579	4985	-2.1562	5225	-7.1858
4050	-9.7364	4750	-4.8555	4990	-2.1732	5230	-7.0633
4055	-9.8771	4755	-4.7213	4995	-2.2913	5235	-6.9962
4060	-9.8840	4760	-4.5868	5000	-2.5476	5240	-6.9905
4065	-9.9559	4765	-4.4594	5005	-2.9382	5245	-7.0319
4530	-9.9489	4770	-4.3387	5010	-3.3966	5250	-7.1331
4535	-9.6003	4775	-4.2219	5015	-3.8525	5255	-7.2054
4540	-9.0910	4780	-4.1002	5020	-4.2541	5260	-7.1856
4545	-8.5793	4785	-3.9812	5025	-4.5682	5265	-7.0561
4550	-8.2059	4790	-3.8876	5030	-4.7376	5270	-6.7966
4555	-7.9099	4795	-3.8207	5035	-4.7524	5275	-6.4771
4560	-7.7157	4800	-3.7673	5040	-4.6733	5280	-6.1996
4565	-7.6145	4805	-3.7120	5045	-4.5170	5285	-5.9593
4570	-7.5964	4810	-3.6223	5050	-4.3123	5290	-5.7560

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
5295	-5.5370	6055	-5.4023	6295	-6.0793	6535	-5.5600
5300	-5.2836	6060	-5.3292	6300	-5.7404	6540	-5.7977
5305	-5.0966	6065	-5.3090	6305	-5.4204	6545	-5.9936
5310	-4.9583	6070	-5.3171	6310	-5.1265	6550	-6.1720
5315	-4.9126	6075	-5.3193	6315	-4.8634	6555	-6.3801
5320	-5.0022	6080	-5.2705	6320	-4.6378	6560	-6.6371
5325	-5.1370	6085	-5.2085	6325	-4.4559	6565	-6.9964
5330	-5.3465	6090	-5.1835	6330	-4.3360	6570	-7.5010
5335	-5.6279	6095	-5.2186	6335	-4.2752	6575	-8.1628
5340	-5.9364	6100	-5.3367	6340	-4.2461	6580	-8.9951
5345	-6.3695	6105	-5.5305	6345	-4.2257	6585	-9.8931
5350	-6.9602	6110	-5.7725	6350	-4.1768	6590	-10.0000
5355	-7.6823	6115	-6.0228	6355	-4.1068	6595	-10.0000
5360	-8.2701	6120	-6.2150	6360	-4.0743	6600	-10.0000
5365	-8.6427	6125	-6.2857	6365	-4.1193	6605	-10.0000
5370	-9.0728	6130	-6.2634	6370	-4.2732	6610	-10.0000
5375	-9.5366	6135	-6.2250	6375	-4.5464	6615	-10.0000
5380	-9.9588	6140	-6.2234	6380	-4.9256	6620	-10.0000
5905	-9.9871	6145	-6.2616	6385	-5.4090	6625	-10.0000
5910	-9.6762	6150	-6.2931	6390	-6.0184	6630	-9.4967
5915	-9.3358	6155	-6.2508	6395	-6.7985	6635	-8.9198
5920	-8.9954	6160	-6.0971	6400	-7.7078	6640	-8.5081
5925	-8.5140	6165	-5.8679	6405	-8.3457	6645	-8.1255
5930	-8.2066	6170	-5.6195	6410	-8.5160	6650	-7.8286
5935	-7.9742	6175	-5.3906	6415	-8.6106	6655	-7.5478
5940	-7.8579	6180	-5.1944	6420	-8.8175	6660	-7.1487
5945	-7.8073	6185	-5.0216	6425	-9.1922	6665	-6.7853
5950	-7.7894	6190	-4.8566	6430	-9.6775	6670	-6.5537
5955	-7.7466	6195	-4.6919	6435	-9.7423	6675	-6.3931
5960	-7.7009	6200	-4.5255	6440	-9.1980	6680	-6.4107
5965	-7.6393	6205	-4.3785	6445	-8.4120	6685	-6.5087
5970	-7.5889	6210	-4.2879	6450	-7.7499	6690	-6.6607
5975	-7.5697	6215	-4.2583	6455	-7.1685	6695	-6.9026
5980	-7.5200	6220	-4.2636	6460	-6.6817	6700	-7.2104
5985	-7.3908	6225	-4.2768	6465	-6.2701	6705	-7.4445
5990	-7.1796	6230	-4.2484	6470	-5.9301	6710	-7.6303
5995	-6.9610	6235	-4.1853	6475	-5.6567	6715	-7.6346
6000	-6.7869	6240	-4.1586	6480	-5.4521	6720	-7.4521
6005	-6.6972	6245	-4.2079	6485	-5.3289	6725	-7.2211
6010	-6.6735	6250	-4.3651	6490	-5.2776	6730	-7.0043
6015	-6.6775	6255	-4.6407	6495	-5.2630	6735	-6.7903
6020	-6.6495	6260	-5.0141	6500	-5.2547	6740	-6.5666
6025	-6.5292	6265	-5.4719	6505	-5.2083	6745	-6.3499
6030	-6.3435	6270	-6.0015	6510	-5.1296	6750	-6.1534
6035	-6.1371	6275	-6.5173	6515	-5.0823	6755	-5.9988
6040	-5.9268	6280	-6.7829	6520	-5.0914	6760	-5.9033
6045	-5.7254	6285	-6.6805	6525	-5.1806	6765	-5.8760
6050	-5.5433	6290	-6.4180	6530	-5.3503	6770	-5.8693

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
6775	-5.8277	7015	-9.0451	7620	-6.2234	8100	-6.6818
6780	-5.7282	7020	-9.5326	7625	-6.6646	8105	-6.6144
6785	-5.6262	7025	-9.8301	7630	-7.2957	8110	-6.5643
6790	-5.5865	7395	-9.9472	7635	-8.2799	8115	-6.5183
6795	-5.6665	7400	-9.8274	7640	-9.9457	8120	-6.4910
6800	-5.9228	7405	-8.9797	7645	-10.0000	8125	-6.4481
6805	-6.3399	7410	-8.4298	7650	-10.0000	8130	-6.3567
6810	-7.0180	7415	-7.8906	7655	-10.0000	8135	-6.2177
6815	-8.4230	7420	-7.4477	7660	-10.0000	8140	-6.0566
6820	-10.0000	7425	-7.0750	7665	-10.0000	8145	-5.9096
6825	-10.0000	7430	-6.7698	7670	-10.0000	8150	-5.7975
6830	-10.0000	7435	-6.5338	7675	-10.0000	8155	-5.7093
6835	-9.4090	7440	-6.3739	7680	-9.2766	8160	-5.6165
6840	-8.8272	7445	-6.2980	7685	-8.6201	8165	-5.5127
6845	-8.3057	7450	-6.2739	7690	-8.0764	8170	-5.4124
6850	-7.8885	7455	-6.2726	7695	-7.6374	8175	-5.3426
6855	-7.5044	7460	-6.2555	7700	-7.2752	8180	-5.3061
6860	-7.1560	7465	-6.1989	7705	-6.9802	8185	-5.2648
6865	-6.8292	7470	-6.1529	7710	-6.7578	8190	-5.1864
6870	-6.5250	7475	-6.1654	7715	-6.6163	8195	-5.0876
6875	-6.2461	7480	-6.2584	7720	-6.5546	8200	-5.0226
6880	-5.9904	7485	-6.4610	7725	-6.5392	8205	-5.0397
6885	-5.7533	7490	-6.7805	7730	-6.5397	8210	-5.1905
6890	-5.5295	7495	-7.2235	7735	-6.5132	8215	-5.4858
6895	-5.3135	7500	-7.8191	7740	-6.4531	8220	-5.9101
6900	-5.1058	7505	-8.5850	7745	-6.4161	8225	-6.4851
6905	-4.9152	7510	-9.6084	7750	-6.4482	8230	-6.7862
6910	-4.7463	7515	-10.0000	7755	-6.5683	8235	-6.5368
6915	-4.6054	7520	-10.0000	7760	-6.8086	8240	-6.2765
6920	-4.4937	7525	-9.9199	7765	-7.1762	8245	-6.0398
6925	-4.3928	7530	-9.1093	7770	-7.6772	8250	-5.8260
6930	-4.2838	7535	-8.4490	7775	-8.3574	8255	-5.6397
6935	-4.1626	7540	-7.9158	7780	-9.2188	8260	-5.4799
6940	-4.0387	7545	-7.4364	7785	-10.0000	8265	-5.3438
6945	-3.9295	7550	-7.0400	8030	-10.0000	8270	-5.2274
6950	-3.8612	7555	-6.6958	8035	-9.5350	8275	-5.1411
6955	-3.8501	7560	-6.4131	8040	-8.9686	8280	-5.0917
6960	-3.8647	7565	-6.1855	8045	-8.5329	8285	-5.0473
6965	-3.8625	7570	-6.0158	8050	-8.1920	8290	-4.9820
6970	-3.8099	7575	-5.9123	8055	-7.9237	8295	-4.9114
6975	-3.7351	7580	-5.8700	8060	-7.6797	8300	-4.8634
6980	-3.7179	7585	-5.8530	8065	-7.5039	8305	-4.8844
6985	-3.8549	7590	-5.8340	8070	-7.3667	8310	-5.0363
6990	-4.2312	7595	-5.7866	8075	-7.2856	8315	-5.3351
6995	-4.7632	7600	-5.7224	8080	-7.1969	8320	-5.7802
7000	-5.4270	7605	-5.7048	8085	-7.0745	8325	-6.5387
7005	-6.4200	7610	-5.7653	8090	-6.9330	8330	-8.3735
7010	-8.1414	7615	-5.9281	8095	-6.7926	8335	-9.9977

C' VALUE FOR CO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
9340	-9.7506	9425	-10.0000	9510	-6.6303	9595	-7.8567
9345	-9.1887	9430	-10.0000	9515	-6.5406	9600	-7.6177
9350	-8.6824	9435	-10.0000	9520	-6.4509	9605	-7.4249
9355	-8.3488	9440	-10.0000	9525	-6.3950	9610	-7.2876
9360	-8.0533	9445	-10.0000	9530	-6.4345	9615	-7.2206
9365	-7.8664	9450	-9.7234	9535	-6.6270	9620	-7.1948
9370	-7.7346	9455	-8.9969	9540	-6.9507	9625	-7.1552
9375	-7.6934	9460	-8.5776	9545	-7.5028	9630	-7.0773
9380	-7.6674	9465	-8.1737	9550	-8.6428	9635	-6.9884
9385	-7.6268	9470	-7.8640	9555	-10.0000	9640	-6.9402
9390	-7.5451	9475	-7.5729	9560	-10.0000	9645	-6.9839
9395	-7.4677	9480	-7.3186	9565	-10.0000	9650	-7.1773
9400	-7.4520	9485	-7.0973	9570	-10.0000	9655	-7.4999
9405	-7.5471	9490	-6.9131	9575	-9.5303	9660	-8.0643
9410	-7.7913	9495	-6.7782	9580	-8.9369	9665	-9.1480
9415	-8.1917	9500	-6.7073	9585	-8.4952	9670	-10.0000
9420	-8.8835	9505	-6.6768	9590	-8.1465		

TABLE A3

C' VALUE FOR CO

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-4.6868	1980	-5.6734	2200	-0.8052	4170	-3.7984
5	-4.4127	1985	-5.2658	2205	-0.9690	4175	-3.6314
10	-3.9461	1990	-4.8686	2210	-1.1506	4180	-3.4757
15	-3.5662	1995	-4.4918	2215	-1.3522	4185	-3.3408
20	-3.2921	2000	-4.1423	2220	-1.5791	4190	-3.2237
25	-3.1081	2005	-3.8133	2225	-1.8248	4195	-3.1219
30	-2.9807	2010	-3.4998	2230	-2.1073	4200	-3.0325
35	-2.8977	2015	-3.2104	2235	-2.4246	4205	-2.9494
40	-2.8580	2020	-2.9443	2240	-2.7877	4210	-2.8765
45	-2.8461	2025	-2.7138	2245	-3.2152	4215	-2.8117
50	-2.8587	2030	-2.5084	2250	-3.7089	4220	-2.7531
55	-2.9029	2035	-2.3109	2255	-4.2832	4225	-2.7023
60	-2.9646	2040	-2.1245	2260	-4.9518	4230	-2.6635
65	-3.0480	2045	-1.9387	2265	-5.7251	4235	-2.6440
70	-3.1589	2050	-1.7608	2270	-6.5319	4240	-2.6550
75	-3.2836	2055	-1.6054	2275	-7.4879	4245	-2.7225
80	-3.4277	2060	-1.4733	2280	-9.0885	4250	-2.8161
85	-3.5993	2065	-1.3594	2285	-10.0000	4255	-2.9015
90	-3.7963	2070	-1.2540	4040	-10.0000	4260	-2.9241
95	-4.0164	2075	-1.1480	4045	-9.5611	4265	-2.8228
100	-4.2799	2080	-1.0341	4050	-9.0875	4270	-2.6726
105	-4.5750	2085	-0.9216	4055	-8.6139	4275	-2.5320
110	-4.8722	2090	-0.8189	4060	-7.9747	4280	-2.4291
115	-5.2741	2095	-0.7235	4065	-7.5250	4285	-2.3772
120	-5.6819	2100	-0.6362	4070	-7.1931	4290	-2.3732
125	-6.0799	2105	-0.5549	4075	-6.8596	4295	-2.3995
130	-6.4828	2110	-0.4856	4080	-6.5741	4300	-2.4574
135	-6.8857	2115	-0.4401	4085	-6.2922	4305	-2.5486
140	-7.2886	2120	-0.4268	4090	-6.0098	4310	-2.6664
145	-7.6915	2125	-0.4657	4095	-5.7669	4315	-2.8209
150	-8.0944	2130	-0.5571	4100	-5.5345	4320	-3.0129
155	-8.4973	2135	-0.6573	4105	-5.3229	4325	-3.2516
160	-8.9002	2140	-0.7404	4110	-5.1461	4330	-3.5482
165	-9.3031	2145	-0.7523	4115	-4.9882	4335	-3.9165
170	-9.7060	2150	-0.6601	4120	-4.8493	4340	-4.3714
175	-10.0000	2155	-0.5380	4125	-4.7239	4345	-4.9326
1940	-10.0000	2160	-0.4211	4130	-4.6064	4350	-5.6394
1945	-9.5312	2165	-0.3367	4135	-4.5009	4355	-6.5163
1950	-8.8977	2170	-0.3167	4140	-4.4071	4360	-7.6063
1955	-8.2642	2175	-0.3320	4145	-4.3322	4365	-9.3575
1960	-7.5767	2180	-0.3753	4150	-4.2661	4370	-10.0000
1965	-6.9972	2185	-0.4489	4155	-4.1926		
1970	-6.5408	2190	-0.5438	4160	-4.0956		
1975	-6.1219	2195	-0.6653	4165	-3.9611		

TABLE A4

C' VALUE FOR CH4

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1065	-10.0000	1305	-0.5027	1545	-2.1488	2350	-9.3577
1070	-9.4577	1310	-0.7628	1550	-2.3261	2355	-8.5950
1075	-8.8866	1315	-0.9625	1555	-2.6448	2360	-7.8323
1080	-8.2246	1320	-1.0431	1560	-3.0446	2365	-7.0696
1085	-7.7940	1325	-1.0068	1565	-3.3958	2370	-6.3069
1090	-7.1734	1330	-0.8781	1570	-3.6510	2375	-5.5442
1095	-6.7965	1335	-0.7559	1575	-3.7049	2380	-5.1501
1100	-6.5695	1340	-0.6628	1580	-3.7240	2385	-4.8853
1105	-6.1929	1345	-0.6128	1585	-3.5992	2390	-4.6900
1110	-5.9169	1350	-0.6118	1590	-3.4937	2395	-4.5262
1115	-5.7452	1355	-0.6575	1595	-3.3676	2400	-4.3957
1120	-5.4731	1360	-0.7620	1600	-3.2230	2405	-4.2823
1125	-5.3001	1365	-0.9217	1605	-3.1630	2410	-4.2736
1130	-5.1872	1370	-1.1264	1610	-3.0691	2415	-4.2054
1135	-4.9672	1375	-1.3660	1615	-3.0776	2420	-4.1168
1140	-4.8474	1380	-1.6352	1620	-3.0872	2425	-3.9986
1145	-4.6939	1385	-1.9264	1625	-3.0974	2430	-3.8712
1150	-4.5210	1390	-2.2266	1630	-3.1223	2435	-3.8692
1155	-4.3377	1395	-2.5123	1635	-3.1285	2440	-3.8777
1160	-4.1346	1400	-2.7472	1640	-3.1212	2445	-3.8965
1165	-3.9322	1405	-2.8820	1645	-3.1333	2450	-3.9092
1170	-3.7339	1410	-2.9129	1650	-3.1674	2455	-3.8788
1175	-3.5077	1415	-2.9145	1655	-3.1668	2460	-3.7661
1180	-3.2719	1420	-2.8854	1660	-3.2433	2465	-3.6900
1185	-3.0296	1425	-2.8508	1665	-3.2398	2470	-3.6239
1190	-2.8124	1430	-2.8512	1670	-3.3135	2475	-3.5597
1195	-2.6199	1435	-2.8202	1675	-3.3975	2480	-3.5193
1200	-2.4479	1440	-2.8023	1680	-3.4427	2485	-3.4906
1205	-2.2502	1445	-2.8004	1685	-3.6434	2490	-3.4415
1210	-2.0541	1450	-2.7800	1690	-3.7528	2495	-3.3730
1215	-1.8800	1455	-2.8175	1695	-3.9466	2500	-3.3579
1220	-1.7092	1460	-2.8413	1700	-4.1940	2505	-3.3427
1225	-1.5791	1465	-2.8943	1705	-4.3362	2510	-3.3208
1230	-1.4379	1470	-2.9876	1710	-4.5539	2515	-3.3048
1235	-1.2992	1475	-3.0688	1715	-4.7410	2520	-3.3136
1240	-1.1735	1480	-3.2424	1720	-4.9155	2525	-3.2904
1245	-1.0510	1485	-3.4064	1725	-5.1345	2530	-3.2545
1250	-0.9646	1490	-3.5759	1730	-5.3908	2535	-3.2241
1255	-0.8779	1495	-3.7630	1735	-5.5592	2540	-3.1453
1260	-0.8002	1500	-3.8925	1740	-5.8270	2545	-3.0187
1265	-0.7574	1505	-4.0774	1745	-6.0289	2550	-2.9427
1270	-0.7356	1510	-4.3243	1750	-6.2365	2555	-2.8630
1275	-0.7478	1515	-4.5964	1755	-6.6730	2560	-2.8146
1280	-0.7512	1520	-3.8654	1760	-7.0538	2565	-2.8604
1285	-0.6906	1525	-3.0974	1765	-7.6216	2570	-2.8922
1290	-0.5594	1530	-2.5967	1770	-8.5697	2575	-2.9650
1295	-0.4417	1535	-2.2482	1775	-9.8483	2580	-2.9959
1300	-0.4019	1540	-2.1016	2345	-10.0000	2585	-2.8920

C' VALUE FOR CH4

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2590	-2.7989	2830	-1.6545	3070	-0.9578	4185	-1.8750
2595	-2.7028	2835	-1.7742	3075	-0.9299	4190	-1.8700
2600	-2.6506	2840	-1.8937	3080	-0.9207	4195	-1.8476
2605	-2.7285	2845	-1.9544	3085	-0.9292	4200	-1.7390
2610	-2.8420	2850	-1.8942	3090	-0.9725	4205	-1.5724
2615	-2.9304	2855	-1.7761	3095	-1.0126	4210	-1.4284
2620	-2.9622	2860	-1.6392	3100	-1.0750	4215	-1.3425
2625	-2.8726	2865	-1.5236	3105	-1.1149	4220	-1.3791
2630	-2.7566	2870	-1.4551	3110	-1.1636	4225	-1.5132
2635	-2.6745	2875	-1.4221	3115	-1.2059	4230	-1.6508
2640	-2.6337	2880	-1.4245	3120	-1.2638	4235	-1.7283
2645	-2.6533	2885	-1.4174	3125	-1.3327	4240	-1.6684
2650	-2.6800	2890	-1.4177	3130	-1.4079	4245	-1.5432
2655	-2.7098	2895	-1.3776	3135	-1.4983	4250	-1.4447
2660	-2.7479	2900	-1.3349	3140	-1.5711	4255	-1.3773
2665	-2.6859	2905	-1.2909	3145	-1.6872	4260	-1.3490
2670	-2.6216	2910	-1.2470	3150	-1.7870	4265	-1.3642
2675	-2.5701	2915	-1.2162	3155	-1.9266	4270	-1.4016
2680	-2.4683	2920	-1.1850	3160	-2.0774	4275	-1.4713
2685	-2.4426	2925	-1.1677	3165	-2.2119	4280	-1.5836
2690	-2.4463	2930	-1.1449	3170	-2.3875	4285	-1.6984
2695	-2.4194	2935	-1.1229	3175	-2.5155	4290	-1.8085
2700	-2.4578	2940	-1.1031	3180	-2.6822	4295	-1.8486
2705	-2.4894	2945	-1.0795	3185	-2.8372	4300	-1.7464
2710	-2.4639	2950	-1.0687	3190	-3.0032	4305	-1.6338
2715	-2.4825	2955	-1.0692	3195	-3.2413	4310	-1.5555
2720	-2.4998	2960	-1.0904	3200	-3.5058	4315	-1.5552
2725	-2.4381	2965	-1.1166	3205	-3.9508	4320	-1.6935
2730	-2.4123	2970	-1.1511	3210	-4.5133	4325	-1.8165
2735	-2.3654	2975	-1.1951	3215	-5.3536	4330	-1.8417
2740	-2.2698	2980	-1.2321	3220	-8.0815	4335	-1.7697
2745	-2.2387	2985	-1.2831	3225	-8.9081	4340	-1.6346
2750	-2.2364	2990	-1.2716	3230	-9.8155	4345	-1.5589
2755	-2.2029	2995	-1.1902	4110	-10.0000	4350	-1.5466
2760	-2.1780	3000	-0.9715	4115	-7.4757	4355	-1.5604
2765	-2.1433	3005	-0.6654	4120	-5.1602	4360	-1.6307
2770	-2.0355	3010	-0.4103	4125	-4.2454	4365	-1.6867
2775	-1.9458	3015	-0.3011	4130	-3.7640	4370	-1.7593
2780	-1.8723	3020	-0.5049	4135	-3.3256	4375	-1.8051
2785	-1.7936	3025	-0.8659	4140	-3.0103	4380	-1.8167
2790	-1.7639	3030	-1.1777	4145	-2.7726	4385	-1.8518
2795	-1.7782	3035	-1.3847	4150	-2.5510	4390	-1.8559
2800	-1.8022	3040	-1.4359	4155	-2.3849	4395	-1.8547
2805	-1.8115	3045	-1.3908	4160	-2.2318	4400	-1.8907
2810	-1.7818	3050	-1.2992	4165	-2.1080	4405	-1.8851
2815	-1.6986	3055	-1.1923	4170	-2.0086	4410	-1.8933
2820	-1.6169	3060	-1.0951	4175	-1.9290	4415	-1.9081
2825	-1.5975	3065	-1.0213	4180	-1.8902	4420	-1.9025

C' VALUE FOR CH4

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
4425	-1.9451	4565	-3.9311	5875	-6.0815	6015	-3.8750
4430	-1.9924	4570	-4.1470	5880	-5.4397	6020	-4.2645
4435	-2.0321	4575	-3.9351	5885	-4.9875	6025	-4.4786
4440	-2.0816	4580	-3.7471	5890	-4.6154	6030	-4.4293
4445	-2.1026	4585	-3.6245	5895	-4.4846	6035	-4.3183
4450	-2.1137	4590	-3.4791	5900	-4.3541	6040	-4.1996
4455	-2.1351	4595	-3.4710	5905	-4.3037	6045	-4.0879
4460	-2.1629	4600	-3.4210	5910	-4.3073	6050	-4.0169
4465	-2.1876	4605	-3.4125	5915	-4.2471	6055	-3.9787
4470	-2.2340	4610	-3.4475	5920	-4.2593	6060	-3.9536
4475	-2.2960	4615	-3.4140	5925	-4.1984	6065	-3.9454
4480	-2.3747	4620	-3.4908	5930	-4.1895	6070	-3.9283
4485	-2.4970	4625	-3.5164	5935	-4.1697	6075	-3.9166
4490	-2.6244	4630	-3.5944	5940	-4.1578	6080	-3.9152
4495	-2.7641	4635	-3.7403	5945	-4.1950	6085	-3.9336
4500	-2.8912	4640	-3.8192	5950	-4.1878	6090	-3.9561
4505	-3.0328	4645	-4.0177	5955	-4.2299	6095	-3.9932
4510	-3.1944	4650	-4.1833	5960	-4.2209	6100	-4.0934
4515	-3.3877	4655	-4.3518	5965	-4.2646	6105	-4.2317
4520	-3.4566	4660	-4.6486	5970	-4.3123	6110	-4.5084
4525	-3.1662	4665	-4.8778	5975	-4.3911	6115	-4.9460
4530	-2.7253	4670	-5.2542	5980	-4.4588	6120	-5.4958
4535	-2.3992	4675	-5.7834	5985	-4.1873	6125	-6.5492
4540	-2.2214	4680	-6.3451	5990	-3.8353	6130	-8.5604
4545	-2.2022	4685	-7.7212	5995	-3.5282	6135	-9.6202
4550	-2.3978	4690	-10.0000	6000	-3.3055		
4555	-2.7449	5865	-9.9134	6005	-3.3351		
4560	-3.2639	5870	-7.9181	6010	-3.5671		

TABLE A5

C' VALUE FOR NO

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1700	-7.9265	1780	-2.7282	1860	-0.6076	1940	-1.3406
1705	-7.5649	1785	-2.4448	1865	-0.6791	1945	-1.6473
1710	-7.2033	1790	-2.1791	1870	-0.7553	1950	-2.0068
1715	-6.8418	1795	-1.9315	1875	-0.7811	1955	-2.4335
1720	-6.4802	1800	-1.7046	1880	-0.7711	1960	-2.9068
1725	-6.0647	1805	-1.4984	1885	-0.6840	1965	-3.4595
1730	-5.7193	1810	-1.3133	1890	-0.5704	1970	-4.0370
1735	-5.3955	1815	-1.1486	1895	-0.4791	1975	-4.6795
1740	-5.1475	1820	-1.0036	1900	-0.4138	1980	-5.2704
1745	-4.8233	1825	-0.8776	1905	-0.3950	1985	-5.8613
1750	-4.5194	1830	-0.7699	1910	-0.4189	1990	-6.4522
1755	-4.3184	1835	-0.6811	1915	-0.4794	1995	-7.0431
1760	-3.9664	1840	-0.6124	1920	-0.5751	2000	-7.6340
1765	-3.7045	1845	-0.5663	1925	-0.7062	2005	-8.0000
1770	-3.3398	1850	-0.5488	1930	-0.8751		
1775	-3.0368	1855	-0.5673	1935	-1.0852		

TABLE A6

C' VALUE FOR NO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
580	-6.0000	760	-1.3284	1525	-4.8964	2805	-5.7606
585	-5.8419	765	-1.2804	1530	-4.2513	2810	-5.3422
590	-5.5313	770	-1.2497	1535	-3.6063	2815	-4.9238
595	-5.1048	775	-1.2519	1540	-2.9612	2820	-4.5055
600	-4.9512	780	-1.3123	1545	-2.1733	2825	-4.0871
605	-4.5830	785	-1.3704	1550	-1.5514	2830	-3.6687
610	-4.2676	790	-1.4192	1555	-1.0260	2835	-3.2504
615	-3.9783	795	-1.4878	1560	-0.5817	2840	-2.8320
620	-3.7150	800	-1.5301	1565	-0.2030	2845	-2.3736
625	-3.4782	805	-1.5575	1570	0.1231	2850	-1.9565
630	-3.2541	810	-1.5912	1575	0.4098	2855	-1.5769
635	-3.0597	815	-1.6250	1580	0.6653	2860	-1.2400
640	-2.8625	820	-1.6544	1585	0.8885	2865	-0.9384
645	-2.6989	825	-1.6849	1590	1.0716	2870	-0.6781
650	-2.5323	830	-1.7340	1595	1.2025	2875	-0.4630
655	-2.3904	835	-1.7748	1600	1.2697	2880	-0.2944
660	-2.2561	840	-1.8171	1605	1.2926	2885	-0.1783
665	-2.1346	845	-1.8679	1610	1.3006	2890	-0.1213
670	-2.0320	850	-1.9256	1615	1.3128	2895	-0.1033
675	-1.9284	855	-1.9809	1620	1.3449	2900	-0.0934
680	-1.8584	860	-2.0386	1625	1.3656	2905	-0.0723
685	-1.7778	865	-2.1112	1630	1.3245	2910	-0.0267
690	-1.7222	870	-2.1769	1635	1.1868	2915	0.0016
695	-1.6776	875	-2.2462	1640	0.9310	2920	-0.0394
700	-1.6024	880	-2.3199	1645	0.5907	2925	-0.1700
705	-1.5658	885	-2.4129	1650	0.2056	2930	-0.4141
710	-1.4917	890	-2.5156	1655	-0.2337	2935	-0.7861
715	-1.4117	895	-2.6575	1660	-0.7633	2940	-1.2951
720	-1.3706	900	-2.8825	1665	-1.4541	2945	-2.0379
725	-1.3045	905	-3.1831	1670	-2.4451	2950	-3.0984
730	-1.2914	910	-3.6209	1675	-3.1822	2955	-3.8692
735	-1.3292	915	-4.2271	1680	-3.9193	2960	-4.6399
740	-1.3666	920	-5.5290	1685	-4.6565	2965	-5.4107
745	-1.4268	925	-6.0000	1690	-5.3936	2970	-6.0000
750	-1.4564	1515	-6.0000	1695	-6.0000		
755	-1.4076	1520	-5.5415	2800	-6.0000		

TABLE A7

C' VALUE FOR N2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-2.8003	605	-0.6521	930	-4.0307	1235	-1.2186
5	-2.6628	610	-0.8148	935	-4.0492	1240	-0.9270
10	-2.4313	615	-1.0186	940	-4.0333	1245	-0.6326
15	-2.2579	620	-1.2764	945	-3.9710	1250	-0.3429
20	-2.1700	625	-1.5873	950	-3.9249	1255	-0.0768
25	-2.1702	630	-1.9638	955	-3.9360	1260	0.1500
30	-2.2490	635	-2.3881	960	-4.0316	1265	0.3215
35	-2.4003	640	-2.8083	965	-4.2317	1270	0.4104
40	-2.6264	645	-3.2392	970	-4.5414	1275	0.4385
45	-2.9219	650	-3.6934	975	-4.9787	1280	0.4288
50	-3.2954	655	-4.0682	980	-5.5623	1285	0.4185
55	-3.7684	660	-4.1366	985	-6.3335	1290	0.4570
60	-4.2621	665	-3.9423	990	-7.9968	1295	0.4972
65	-4.7558	670	-3.7143	995	-9.6601	1300	0.4987
70	-5.2495	675	-3.4975	1065	-9.5486	1305	0.4216
75	-5.7432	680	-3.2602	1070	-8.8517	1310	0.2360
80	-6.2369	685	-3.0976	1075	-8.1548	1315	-0.0319
85	-6.7306	690	-2.9815	1080	-7.4579	1320	-0.3714
90	-7.2243	695	-2.9153	1085	-6.7610	1325	-0.7539
95	-7.7180	700	-2.9596	1090	-6.0641	1330	-1.1534
100	-8.2117	705	-3.0281	1095	-5.3672	1335	-1.5855
105	-8.7054	710	-3.1264	1100	-4.6703	1340	-2.0610
110	-9.1991	715	-3.2650	1105	-3.6918	1345	-2.6068
115	-9.6928	720	-3.3906	1110	-3.0656	1350	-3.2635
120	-10.0000	725	-3.5717	1115	-2.5796	1355	-4.1038
490	-9.7185	730	-3.8312	1120	-2.1876	1360	-5.2761
495	-8.8926	735	-4.1706	1125	-1.8646	1365	-6.1437
500	-8.0667	740	-4.6077	1130	-1.5919	1370	-7.0079
505	-7.2307	745	-5.1839	1135	-1.3587	1375	-7.9440
510	-6.4149	750	-5.9224	1140	-1.1684	1380	-8.8801
515	-5.4872	755	-6.9862	1145	-1.0286	1385	-9.8162
520	-4.7083	760	-7.6901	1150	-0.9470	1545	-10.0000
525	-4.0319	765	-8.3940	1155	-0.9271	1550	-9.5951
530	-3.4752	770	-9.0979	1160	-0.9442	1555	-9.1305
535	-3.0155	775	-9.8018	1165	-0.9695	1560	-8.6659
540	-2.6046	865	-9.9154	1170	-0.9753	1565	-8.2013
545	-2.2057	870	-9.2271	1175	-0.9573	1570	-7.7367
550	-1.8137	875	-8.5388	1180	-0.9550	1575	-7.2721
555	-1.4741	880	-7.8504	1185	-1.0000	1580	-6.8075
560	-1.1914	885	-7.1621	1190	-1.1070	1585	-6.1598
565	-0.9603	890	-6.2428	1195	-1.2791	1590	-5.8695
570	-0.7923	895	-5.6051	1200	-1.4976	1595	-5.3510
575	-0.6629	900	-5.0971	1205	-1.7281	1600	-4.9491
580	-0.5849	905	-4.7237	1210	-1.9277	1605	-4.6310
585	-0.5402	910	-4.4104	1215	-2.0227	1610	-4.3846
590	-0.4975	915	-4.2050	1220	-1.9577	1615	-4.0784
595	-0.5148	920	-4.0681	1225	-1.7625	1620	-3.7763
600	-0.5592	925	-4.0278	1230	-1.5020	1625	-3.5901

C' VALUE FOR N2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1630	-3.4607	1870	-2.5615	2155	-1.1580	2395	-7.3571
1635	-3.4386	1875	-2.4382	2160	-0.8445	2400	-5.0287
1640	-3.5481	1880	-2.3523	2165	-0.5455	2405	-4.3047
1645	-3.7014	1885	-2.3774	2170	-0.2506	2410	-3.6431
1650	-3.9310	1890	-2.4508	2175	0.0234	2415	-3.1026
1655	-4.2251	1895	-2.5755	2180	0.2775	2420	-2.6122
1660	-4.4593	1900	-2.7757	2185	0.5113	2425	-2.1941
1665	-4.8210	1905	-2.9904	2190	0.7154	2430	-1.8454
1670	-5.3494	1910	-3.2733	2195	0.8929	2435	-1.5726
1675	-6.1286	1915	-3.6524	2200	1.0359	2440	-1.3829
1680	-7.5981	1920	-4.1599	2205	1.1306	2445	-1.2818
1685	-10.0000	1925	-4.7952	2210	1.1697	2450	-1.2505
1690	-10.0000	1930	-5.7004	2215	1.1807	2455	-1.2579
1695	-10.0000	1935	-6.8762	2220	1.1803	2460	-1.2731
1700	-10.0000	1940	-6.9822	2225	1.1974	2465	-1.2502
1705	-6.3743	1945	-6.2484	2230	1.2466	2470	-1.2092
1710	-5.5592	1950	-5.7613	2235	1.2629	2475	-1.2044
1715	-5.0129	1955	-5.2586	2240	1.2068	2480	-1.2577
1720	-4.6075	1960	-4.8674	2245	1.0472	2485	-1.3942
1725	-4.3171	1965	-4.6633	2250	0.7695	2490	-1.6262
1730	-4.0928	1970	-4.5332	2255	0.4083	2495	-1.9347
1735	-3.7537	1975	-4.5158	2260	-0.0244	2500	-2.2830
1740	-3.5406	1980	-4.6593	2265	-0.5477	2505	-2.5386
1745	-3.3869	1985	-4.8427	2270	-1.2202	2510	-2.4801
1750	-3.2913	1990	-5.0917	2275	-2.1067	2515	-2.1671
1755	-3.3633	1995	-5.5781	2280	-2.9508	2520	-1.8061
1760	-3.4932	2000	-6.0645	2285	-3.2107	2525	-1.4726
1765	-3.6924	2005	-6.5509	2290	-3.1587	2530	-1.1797
1770	-4.0074	2010	-7.0373	2295	-2.9600	2535	-0.9377
1775	-4.2504	2015	-7.5237	2300	-2.7641	2540	-0.7542
1780	-4.5389	2020	-8.0101	2305	-2.6324	2545	-0.6392
1785	-4.9425	2025	-8.4965	2310	-2.5671	2550	-0.5899
1790	-5.4741	2030	-8.9829	2315	-2.5664	2555	-0.5743
1795	-6.2069	2035	-9.4693	2320	-2.6088	2560	-0.5669
1800	-7.5981	2040	-9.9557	2325	-2.6425	2565	-0.5339
1805	-10.0000	2090	-9.7130	2330	-2.6606	2570	-0.4745
1810	-10.0000	2095	-8.6609	2335	-2.6895	2575	-0.4471
1815	-10.0000	2100	-7.6089	2340	-2.7551	2580	-0.4779
1820	-6.9215	2105	-6.5568	2345	-2.8837	2585	-0.5877
1825	-6.0798	2110	-5.0880	2350	-3.0884	2590	-0.7964
1830	-5.1934	2115	-4.4527	2355	-3.3746	2595	-1.0942
1835	-4.6288	2120	-3.9302	2360	-3.7078	2600	-1.4812
1840	-4.1316	2125	-3.4438	2365	-4.0975	2605	-1.9593
1845	-3.7322	2130	-2.9701	2370	-4.6272	2610	-2.5140
1850	-3.4089	2135	-2.5423	2375	-5.2484	2615	-3.1350
1855	-3.1573	2140	-2.1616	2380	-10.0000	2620	-3.8102
1860	-2.9573	2145	-1.8076	2385	-10.0000	2625	-4.5825
1865	-2.7298	2150	-1.4763	2390	-10.0000	2630	-5.5982

C' VALUE FOR N2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2635	-6.4193	3295	-4.4643	3535	-6.0119	3775	-2.3366
2640	-7.2403	3300	-3.9624	3540	-6.9457	3780	-2.6293
2645	-8.0614	3305	-3.5231	3545	-10.0000	3785	-2.8922
2650	-8.8825	3310	-3.1395	3550	-10.0000	3790	-2.9474
2655	-9.7035	3315	-2.8067	3555	-10.0000	3795	-2.7627
2705	-9.8910	3320	-2.5232	3560	-10.0000	3800	-2.4999
2710	-8.9876	3325	-2.2858	3565	-7.0394	3805	-2.2554
2715	-8.0843	3330	-2.0820	3570	-5.9637	3810	-2.0537
2720	-7.1809	3335	-1.9049	3575	-5.2317	3815	-1.9062
2725	-6.1501	3340	-1.7554	3580	-4.6419	3820	-1.8268
2730	-5.3742	3345	-1.6485	3585	-4.1663	3825	-1.7941
2735	-4.7352	3350	-1.5959	3590	-3.7874	3830	-1.7766
2740	-4.2051	3355	-1.5838	3595	-3.5000	3835	-1.7468
2745	-3.7525	3360	-1.5961	3600	-3.3086	3840	-1.6767
2750	-3.3562	3365	-1.5997	3605	-3.2143	3845	-1.6130
2755	-2.9916	3370	-1.5734	3610	-3.1926	3850	-1.6085
2760	-2.6649	3375	-1.5615	3615	-3.2105	3855	-1.6849
2765	-2.3872	3380	-1.5974	3620	-3.2308	3860	-1.8599
2770	-2.1499	3385	-1.7059	3625	-3.1971	3865	-2.1258
2775	-1.9747	3390	-1.9034	3630	-3.1510	3870	-2.4538
2780	-1.7982	3395	-2.1631	3635	-3.1402	3875	-2.8205
2785	-1.6518	3400	-2.4181	3640	-3.1969	3880	-3.2028
2790	-1.5582	3405	-2.5427	3645	-3.3477	3885	-3.5988
2795	-1.4838	3410	-2.4592	3650	-3.6005	3890	-4.0691
2800	-1.5004	3415	-2.2513	3655	-3.9534	3895	-4.7117
2805	-1.5821	3420	-2.0187	3660	-4.4117	3900	-5.6320
2810	-1.6912	3425	-1.7879	3665	-4.9729	3905	-6.4806
2815	-1.8673	3430	-1.5612	3670	-5.6009	3910	-7.3731
2820	-2.0756	3435	-1.3399	3675	-6.2179	3915	-8.2602
2825	-2.3351	3440	-1.1265	3680	-5.9845	3920	-9.1474
2830	-2.7020	3445	-0.9226	3685	-5.5502	3925	-10.0000
2835	-3.1921	3450	-0.7379	3690	-4.9010	4260	-10.0000
2840	-3.8409	3455	-0.5790	3695	-4.3401	4265	-9.5340
2845	-4.7085	3460	-0.4573	3700	-3.8232	4270	-9.0282
2850	-5.9588	3465	-0.3952	3705	-3.3802	4275	-8.5224
2855	-6.5829	3470	-0.3683	3710	-2.9972	4280	-8.0166
2860	-8.5585	3475	-0.3511	3715	-2.6747	4285	-7.5109
2865	-9.8584	3480	-0.3216	3720	-2.4143	4290	-7.0051
3245	-9.9723	3485	-0.2556	3725	-2.2209	4295	-6.4117
3250	-9.4215	3490	-0.2126	3730	-2.1080	4300	-6.0148
3255	-8.8707	3495	-0.2593	3735	-2.0682	4305	-5.4878
3260	-8.3199	3500	-0.4361	3740	-2.0687	4310	-5.1742
3265	-7.7691	3505	-0.7702	3745	-2.0775	4315	-4.8859
3270	-7.2183	3510	-1.2089	3750	-2.0485	4320	-4.4873
3275	-6.5567	3515	-1.7060	3755	-1.9847	4325	-4.2249
3280	-6.4345	3520	-2.2937	3760	-1.9531	4330	-4.0285
3285	-5.6448	3525	-3.1133	3765	-1.9870	4335	-3.8669
3290	-5.0529	3530	-4.4419	3770	-2.1110	4340	-3.8247

C' VALUE FOR N2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
4345	-3.7652	4570	-6.2415	4730	-2.0142	5010	-3.6435
4350	-3.6521	4575	-5.5829	4735	-1.9239	5015	-3.6326
4355	-3.4906	4580	-5.0296	4740	-1.8618	5020	-3.6339
4360	-3.2613	4585	-4.5660	4745	-1.8813	5025	-3.6157
4365	-3.0307	4590	-4.1722	4750	-2.0099	5030	-3.5478
4370	-2.8156	4595	-3.8364	4755	-2.2825	5035	-3.4826
4375	-2.6172	4600	-3.5551	4760	-2.7071	5040	-3.4807
4380	-2.4264	4605	-3.3398	4765	-3.3277	5045	-3.5665
4385	-2.2442	4610	-3.1970	4770	-4.3300	5050	-3.7650
4390	-2.0775	4615	-3.1363	4775	-6.2151	5055	-4.0718
4395	-1.9432	4620	-3.1232	4780	-8.3543	5060	-4.3980
4400	-1.8703	4625	-3.1257	4785	-10.0000	5065	-4.5075
4405	-1.8523	4630	-3.0999	4910	-9.7275	5070	-4.3358
4410	-1.8552	4635	-3.0288	4915	-9.1257	5075	-4.0765
4415	-1.8443	4640	-2.9746	4920	-8.5239	5080	-3.8674
4420	-1.7814	4645	-2.9875	4925	-7.9221	5085	-3.7221
4425	-1.7104	4650	-3.0925	4930	-7.3203	5090	-3.6588
4430	-1.7043	4655	-3.3137	4935	-6.7185	5095	-3.6429
4435	-1.7952	4660	-3.6496	4940	-6.6089	5100	-3.6371
4440	-2.0205	4665	-4.0276	4945	-5.8877	5105	-3.6014
4445	-2.3968	4670	-4.1958	4950	-5.4527	5110	-3.5209
4450	-2.9374	4675	-3.9760	4955	-5.0879	5115	-3.4616
4455	-3.7689	4680	-3.6179	4960	-4.6598	5120	-3.4774
4460	-5.3159	4685	-3.2725	4965	-4.3806	5125	-3.5957
4465	-7.4139	4690	-2.9653	4970	-4.1830	5130	-3.8481
4470	-9.5119	4695	-2.6962	4975	-4.0426	5135	-4.2598
4540	-9.7965	4700	-2.4677	4980	-4.0175	5140	-4.8784
4545	-9.1511	4705	-2.2828	4985	-4.0178	5145	-5.8266
4550	-8.5057	4710	-2.1547	4990	-3.9811	5150	-6.7468
4555	-7.8603	4715	-2.0949	4995	-3.9244	5155	-8.1352
4560	-7.2149	4720	-2.0763	5000	-3.8056	5160	-9.2208
4565	-6.5695	4725	-2.0606	5005	-3.6968	5165	-10.0000

TABLE A8

C' VALUE FOR O2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-6.1363	240	-12.4360	7860	-7.4194	9250	-13.3447
5	-6.1794	245	-12.7437	7865	-7.2688	9255	-13.1523
10	-6.2538	250	-13.0514	7870	-7.0722	9260	-12.9600
15	-6.3705	255	-13.3591	7875	-6.8815	9265	-12.7677
20	-6.5110	260	-13.6668	7880	-6.7627	9270	-12.5754
25	-6.6162	265	-13.9745	7885	-6.8055	9275	-12.3830
30	-6.7505	7650	-13.9458	7890	-6.9114	9280	-12.1907
35	-6.7896	7655	-13.7692	7895	-6.9936	9285	-11.9948
40	-6.8305	7660	-13.5048	7900	-7.0519	9290	-11.7759
45	-6.8471	7665	-13.1422	7905	-7.0597	9295	-11.5926
50	-6.8282	7670	-13.0242	7910	-7.0680	9300	-11.4214
55	-6.8772	7675	-12.6684	7915	-7.1242	9305	-11.2493
60	-6.8680	7680	-12.3571	7920	-7.2088	9310	-11.1094
65	-6.9332	7685	-12.2428	7925	-7.3265	9315	-10.9477
70	-6.9511	7690	-11.8492	7930	-7.4673	9320	-10.8332
75	-7.0048	7695	-11.6427	7935	-7.6326	9325	-10.7323
80	-7.0662	7700	-11.5173	7940	-7.8110	9330	-10.6380
85	-7.1043	7705	-11.2108	7945	-8.0096	9335	-10.5725
90	-7.2055	7710	-11.1584	7950	-8.2104	9340	-10.4409
95	-7.2443	7715	-11.0196	7955	-8.4036	9345	-10.2013
100	-7.3520	7720	-10.8040	7960	-8.5853	9350	-9.8839
105	-7.4079	7725	-10.8059	7965	-8.7252	9355	-9.6546
110	-7.4998	7730	-10.5828	7970	-8.8511	9360	-9.5053
115	-7.5924	7735	-10.4580	7975	-8.9427	9365	-9.4638
120	-7.6682	7740	-10.4170	7980	-9.0375	9370	-9.5526
125	-7.7993	7745	-10.1823	7985	-9.1228	9375	-9.6558
130	-7.8712	7750	-10.1435	7990	-9.2246	9380	-9.7430
135	-8.0161	7755	-10.0030	7995	-9.3291	9385	-9.7958
140	-8.1102	7760	-9.8136	8000	-9.4436	9390	-9.7896
145	-8.2485	7765	-9.7772	8005	-9.5716	9395	-9.8320
150	-8.3758	7770	-9.5680	8010	-9.6951	9400	-9.9447
155	-8.4942	7775	-9.4595	8015	-9.8408	9405	-10.1221
160	-8.6532	7780	-9.3502	8020	-9.9759	9410	-10.3707
165	-8.7554	7785	-9.1411	8025	-10.1489	9415	-10.6623
170	-8.9453	7790	-9.0476	8030	-10.3027	9420	-10.9761
175	-9.0665	7795	-8.8628	8035	-10.5178	9425	-11.2271
180	-9.2631	7800	-8.7051	8040	-10.7265	9430	-11.4091
185	-9.4387	7805	-8.5838	8045	-10.9787	9435	-11.4921
190	-9.6325	7810	-8.4282	8050	-11.2939	9440	-11.6015
195	-9.8757	7815	-8.3271	8055	-11.5552	9445	-11.6945
200	-10.0628	7820	-8.1958	8060	-11.9595	9450	-11.8333
205	-10.3761	7825	-8.0838	8065	-12.2436	9455	-11.9985
210	-10.5478	7830	-7.9652	8070	-12.6942	9460	-12.1788
215	-10.9147	7835	-7.8371	8075	-13.2011	9465	-12.3822
220	-11.2052	7840	-7.7476	8080	-13.8191	9470	-12.6605
225	-11.5129	7845	-7.6431	9235	-13.9216	9475	-13.0796
230	-11.8206	7850	-7.5736	9240	-13.7293	9480	-13.3528
235	-12.1283	7855	-7.5149	9245	-13.5370	9485	-13.6463

C' VALUE FOR O2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
9490	-13.9398	13085	-5.4002	14400	-8.8060	15730	-12.2852
12850	-13.7034	13090	-5.3413	14405	-8.6543	15735	-11.9331
12855	-13.3150	13095	-5.2826	14410	-8.5441	15740	-11.7575
12860	-13.1177	13100	-5.2458	14415	-8.3556	15745	-11.6297
12865	-12.6462	13105	-5.2877	14420	-8.2557	15750	-11.3290
12870	-12.4868	13110	-5.3743	14425	-8.0959	15755	-11.1205
12875	-12.2205	13115	-5.4654	14430	-7.9717	15760	-11.0084
12880	-11.9650	13120	-5.5262	14435	-7.8453	15765	-10.7243
12885	-11.6941	13125	-5.4429	14440	-7.7076	15770	-10.5543
12890	-11.4377	13130	-5.2430	14445	-7.5910	15775	-10.4485
12895	-11.2136	13135	-5.0284	14450	-7.4567	15780	-10.1764
12900	-10.9567	13140	-4.8464	14455	-7.3439	15785	-10.0759
12905	-10.7980	13145	-4.7534	14460	-7.2248	15790	-9.9304
12910	-10.5546	13150	-4.7825	14465	-7.1236	15795	-9.7196
12915	-10.3952	13155	-4.9462	14470	-7.0209	15800	-9.6630
12920	-10.2403	13160	-5.2290	14475	-6.9345	15805	-9.4774
12925	-10.0491	13165	-5.6440	14480	-6.8404	15810	-9.3638
12930	-9.9226	13170	-6.1889	14485	-6.7560	15815	-9.2675
12935	-9.7871	13175	-6.8427	14490	-6.6744	15820	-9.1121
12940	-9.6557	13180	-7.7731	14495	-6.5870	15825	-9.0368
12945	-9.6106	13185	-9.1688	14500	-6.5278	15830	-8.9025
12950	-9.5142	13190	-9.6893	14505	-6.4809	15835	-8.8028
12955	-9.4763	13195	-10.1853	14510	-6.5042	15840	-8.7012
12960	-9.4163	13200	-10.7670	14515	-6.5797	15845	-8.5909
12965	-9.2348	13205	-11.4611	14520	-6.6564	15850	-8.5121
12970	-9.1088	13210	-12.3081	14525	-6.6939	15855	-8.4141
12975	-8.7946	13215	-13.1476	14530	-6.5912	15860	-8.3444
12980	-8.5876	13220	-13.8192	14535	-6.3776	15865	-8.2687
12985	-8.3128	14300	-13.5871	14540	-6.1438	15870	-8.2003
12990	-8.0945	14305	-13.2189	14545	-6.0062	15875	-8.1571
12995	-7.9127	14310	-12.9705	14550	-6.0469	15880	-8.1141
13000	-7.7229	14315	-12.4825	14555	-6.3081	15885	-8.1261
13005	-7.5860	14320	-12.1301	14560	-6.8199	15890	-8.1848
13010	-7.4215	14325	-11.9430	14565	-7.4307	15895	-8.2395
13015	-7.2726	14330	-11.6636	14570	-8.1345	15900	-8.2478
13020	-7.1179	14335	-11.3197	14575	-9.1190	15905	-8.0877
13025	-6.9516	14340	-11.1678	14580	-10.4203	15910	-7.7980
13030	-6.8075	14345	-10.8967	14585	-11.4698	15915	-7.5611
13035	-6.6413	14350	-10.6002	14590	-12.5942	15920	-7.4437
13040	-6.5043	14355	-10.4857	14595	-13.5316	15925	-7.4880
13045	-6.3519	14360	-10.1986	14600	-13.8693	15930	-7.7644
13050	-6.2112	14365	-9.9731	15695	-13.9392	15935	-8.2142
13055	-6.0839	14370	-9.8547	15700	-13.6885	15940	-8.8765
13060	-5.9337	14375	-9.5817	15705	-13.4377	15945	-10.1091
13065	-5.8321	14380	-9.4382	15710	-13.1869	15950	-12.4493
13070	-5.6969	14385	-9.3042	15715	-12.9362	15955	-13.7228
13075	-5.5923	14390	-9.0755	15720	-12.6854		
13080	-5.5076	14395	-8.9944	15725	-12.3720		

TABLE A9

C' VALUE FOR O3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-2.0427	550	-5.9282	790	-1.9051	1030	0.7752
5	-1.8966	555	-5.6426	795	-2.0383	1035	0.7826
10	-1.6263	560	-5.3570	800	-2.1796	1040	0.7874
15	-1.3896	565	-5.0714	805	-2.3312	1045	0.8006
20	-1.2170	570	-4.7858	810	-2.4906	1050	0.8241
25	-1.0996	575	-4.5002	815	-2.6569	1055	0.7614
30	-1.0214	580	-4.2146	820	-2.8354	1060	0.5662
35	-0.9673	585	-3.9290	825	-3.0179	1065	0.1949
40	-0.9249	590	-3.6213	830	-3.2121	1070	-0.2770
45	-0.8896	595	-3.3407	835	-3.4106	1075	-0.6199
50	-0.8612	600	-3.0722	840	-3.6208	1080	-0.8347
55	-0.8417	605	-2.8226	845	-3.8332	1085	-0.9586
60	-0.8360	610	-2.5914	850	-4.0584	1090	-1.0168
65	-0.8483	615	-2.3778	855	-4.2854	1095	-1.0501
70	-0.8785	620	-2.1823	860	-4.4979	1100	-1.0816
75	-0.9273	625	-2.0057	865	-4.7175	1105	-1.0980
80	-0.9932	630	-1.8456	870	-4.9109	1110	-1.0833
85	-1.0720	635	-1.6991	875	-5.1246	1115	-1.0424
90	-1.1639	640	-1.5659	880	-5.3344	1120	-0.9972
95	-1.2662	645	-1.4436	885	-5.5442	1125	-0.9724
100	-1.3771	650	-1.3323	890	-5.7540	1130	-0.9855
105	-1.4976	655	-1.2319	895	-5.9638	1135	-1.0365
110	-1.6274	660	-1.1407	900	-6.1736	1140	-1.1187
115	-1.7712	665	-1.0550	905	-6.3834	1145	-1.2150
120	-1.9289	670	-0.9733	910	-6.5932	1150	-1.3142
125	-2.1027	675	-0.9033	915	-6.8030	1155	-1.4103
130	-2.2948	680	-0.8584	920	-7.0128	1160	-1.4998
135	-2.4987	685	-0.8527	925	-6.9011	1165	-1.5933
140	-2.7321	690	-0.8838	930	-6.2590	1170	-1.6938
145	-2.9992	695	-0.9219	935	-5.8119	1175	-1.8061
150	-3.3045	700	-0.9360	940	-5.1603	1180	-1.9332
155	-3.6994	705	-0.9025	945	-4.3327	1185	-2.0737
160	-4.1022	710	-0.8402	950	-3.6849	1190	-2.2279
165	-4.6467	715	-0.7913	955	-3.1253	1195	-2.3966
170	-5.1328	720	-0.7794	960	-2.6304	1200	-2.5787
175	-5.6481	725	-0.8123	965	-2.1903	1205	-2.7755
180	-6.1634	730	-0.8750	970	-1.8019	1210	-2.9855
185	-6.6787	735	-0.9484	975	-1.4585	1215	-3.2090
190	-7.1940	740	-1.0206	980	-1.1533	1220	-3.4465
195	-7.7093	745	-1.0864	985	-0.8770	1225	-3.6967
200	-8.0000	750	-1.1520	990	-0.6166	1230	-3.9633
515	-7.9274	755	-1.2202	995	-0.3630	1235	-4.2461
520	-7.6418	760	-1.2928	1000	-0.1102	1240	-4.5502
525	-7.3562	765	-1.3745	1005	0.1336	1245	-4.8912
530	-7.0706	770	-1.4641	1010	0.3525	1250	-5.2845
535	-6.7850	775	-1.5611	1015	0.5326	1255	-5.7654
540	-6.4994	780	-1.6669	1020	0.6678	1260	-6.4194
545	-6.2138	785	-1.7816	1025	0.7510	1265	-6.9288

C' VALUE FOR O3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1270	-7.4382	1860	-3.0873	2100	-0.3274	2710	-5.0899
1275	-7.9476	1865	-3.1844	2105	-0.3133	2715	-4.7297
1630	-8.0000	1870	-3.2929	2110	-0.3023	2720	-4.3694
1635	-7.5432	1875	-3.4158	2115	-0.2859	2725	-3.9462
1640	-6.9273	1880	-3.5361	2120	-0.3055	2730	-3.6022
1645	-6.3115	1885	-3.6710	2125	-0.4374	2735	-3.2886
1650	-5.5431	1890	-3.8062	2130	-0.6972	2740	-3.0234
1655	-4.9563	1895	-3.9520	2135	-1.1064	2745	-2.7863
1660	-4.4640	1900	-4.1140	2140	-1.4904	2750	-2.5797
1665	-4.0371	1905	-4.2635	2145	-1.9687	2755	-2.4073
1670	-3.6533	1910	-4.4395	2150	-2.4498	2760	-2.2760
1675	-3.3069	1915	-4.6138	2155	-2.5971	2765	-2.1894
1680	-2.9877	1920	-4.8372	2160	-2.5220	2770	-2.1359
1685	-2.7042	1925	-5.0837	2165	-2.4301	2775	-2.1160
1690	-2.4507	1930	-5.3302	2170	-2.3467	2780	-2.0808
1695	-2.2355	1935	-5.3665	2175	-2.2901	2785	-2.0151
1700	-2.0651	1940	-5.4358	2180	-2.2746	2790	-1.9666
1705	-1.9477	1945	-5.0651	2185	-2.3021	2795	-1.9409
1710	-1.8705	1950	-4.8416	2190	-2.3635	2800	-1.9868
1715	-1.8422	1955	-4.5293	2195	-2.4420	2805	-2.1450
1720	-1.8235	1960	-4.2547	2200	-2.5088	2810	-2.3965
1725	-1.7782	1965	-4.0039	2205	-2.5485	2815	-2.8042
1730	-1.7367	1970	-3.7818	2210	-2.5617	2820	-3.5500
1735	-1.7012	1975	-3.5850	2215	-2.5656	2825	-4.8275
1740	-1.7208	1980	-3.4091	2220	-2.5771	2830	-5.6378
1745	-1.8353	1985	-3.2509	2225	-2.6134	2835	-6.4482
1750	-2.0331	1990	-3.0934	2230	-2.6822	2840	-7.2585
1755	-2.3077	1995	-2.9485	2235	-2.7885	2845	-8.0000
1760	-2.5996	2000	-2.8055	2240	-2.9379	2850	-8.0000
1765	-2.7517	2005	-2.6705	2245	-3.1200	2855	-7.6278
1770	-2.7263	2010	-2.5482	2250	-3.3260	2860	-7.2556
1775	-2.6671	2015	-2.4362	2255	-3.5464	2865	-6.8834
1780	-2.6415	2020	-2.3380	2260	-3.7736	2870	-6.5111
1785	-2.6449	2025	-2.2486	2265	-4.0311	2875	-6.1389
1790	-2.6613	2030	-2.1645	2270	-4.3651	2880	-5.7667
1795	-2.6589	2035	-2.0834	2275	-4.7794	2885	-5.3945
1800	-2.6083	2040	-2.0035	2280	-5.5152	2890	-5.0223
1805	-2.5250	2045	-1.9081	2285	-6.1240	2895	-4.6501
1810	-2.4529	2050	-1.7681	2290	-7.2193	2900	-4.2779
1815	-2.4157	2055	-1.5768	2295	-8.0000	2905	-3.9056
1820	-2.4298	2060	-1.3615	2670	-7.9721	2910	-3.5334
1825	-2.4906	2065	-1.1463	2675	-7.6118	2915	-3.3828
1830	-2.5823	2070	-0.9482	2680	-7.2515	2920	-3.2452
1835	-2.6873	2075	-0.7800	2685	-6.8913	2925	-3.1411
1840	-2.7808	2080	-0.6336	2690	-6.5310	2930	-3.0403
1845	-2.8612	2085	-0.5092	2695	-6.1707	2935	-2.9428
1850	-2.9303	2090	-0.4105	2700	-5.8105	2940	-2.8436
1855	-3.0022	2095	-0.3495	2705	-5.4502	2945	-2.7573

C' VALUE FOR O3

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2950	-2.6853	3030	-1.1707	3110	-2.6154	3190	-2.6499
2955	-2.6040	3035	-1.1609	3115	-2.5570	3195	-2.7694
2960	-2.5218	3040	-1.1609	3120	-2.4983	3200	-2.9057
2965	-2.4121	3045	-1.1805	3125	-2.4480	3205	-3.0286
2970	-2.3547	3050	-1.1999	3130	-2.3890	3210	-3.1543
2975	-2.1970	3055	-1.4214	3135	-2.3663	3215	-3.3696
2980	-2.0668	3060	-1.6348	3140	-2.3431	3220	-3.6053
2985	-1.9121	3065	-1.7519	3145	-2.3314	3225	-4.1977
2990	-1.7617	3070	-1.9730	3150	-2.3200	3230	-4.7811
2995	-1.6153	3075	-2.2078	3155	-2.3200	3235	-5.2933
3000	-1.4688	3080	-2.4608	3160	-2.3314	3240	-5.7554
3005	-1.4022	3085	-2.5337	3165	-2.3431	3245	-6.4542
3010	-1.3447	3090	-2.5923	3170	-2.3547	3250	-7.0239
3015	-1.2669	3095	-2.6616	3175	-2.3777	3255	-7.5937
3020	-1.1902	3100	-2.6384	3180	-2.4004	3260	-8.0000
3025	-1.1805	3105	-2.6271	3185	-2.5218		

TABLE A10

C' VALUE FOR SO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-0.9312	450	-1.6307	985	-6.0129	1225	-1.1305
5	-0.8101	455	-1.3056	990	-5.7390	1230	-1.3036
10	-0.5729	460	-1.0373	995	-5.4651	1235	-1.4924
15	-0.3590	465	-0.8189	1000	-5.1912	1240	-1.7000
20	-0.2016	470	-0.6395	1005	-4.9173	1245	-1.9306
25	-0.0971	475	-0.4880	1010	-4.6434	1250	-2.1906
30	-0.0333	480	-0.3574	1015	-4.3695	1255	-2.4959
35	0.0048	485	-0.2369	1020	-4.0956	1260	-2.8613
40	0.0228	490	-0.1237	1025	-3.8217	1265	-3.3176
45	0.0214	495	-0.0261	1030	-3.5478	1270	-3.9236
50	-0.0044	500	0.0250	1035	-3.2739	1275	-4.6847
55	-0.0567	505	0.0186	1040	-3.0000	1280	-5.2561
60	-0.1334	510	-0.0194	1045	-2.7261	1285	-4.7082
65	-0.2315	515	-0.0659	1050	-2.4522	1290	-4.1110
70	-0.3451	520	-0.0638	1055	-2.1783	1295	-3.6582
75	-0.4741	525	-0.0065	1060	-1.9317	1300	-3.1963
80	-0.6198	530	0.0468	1065	-1.7073	1305	-2.7063
85	-0.7854	535	0.0682	1070	-1.5004	1310	-1.9643
90	-0.9764	540	0.0355	1075	-1.3136	1315	-1.3089
95	-1.1922	545	-0.0431	1080	-1.1444	1320	-0.6856
100	-1.4326	550	-0.1334	1085	-0.9901	1325	-0.0412
105	-1.6951	555	-0.2175	1090	-0.8505	1330	0.3678
110	-1.9687	560	-0.2954	1095	-0.7238	1335	0.6712
115	-2.2788	565	-0.3738	1100	-0.6083	1340	0.9031
120	-2.6034	570	-0.4588	1105	-0.5025	1345	1.0577
125	-2.9398	575	-0.5571	1110	-0.4016	1350	1.1145
130	-3.3551	580	-0.6729	1115	-0.3047	1355	1.1272
135	-3.7704	585	-0.8131	1120	-0.2112	1360	1.1300
140	-4.1857	590	-0.9805	1125	-0.1263	1365	1.1237
145	-4.6010	595	-1.1831	1130	-0.0656	1370	1.1459
150	-5.0163	600	-1.4334	1135	-0.0414	1375	1.1047
155	-5.4316	605	-1.7354	1140	-0.0509	1380	0.9617
160	-5.8469	610	-2.1065	1145	-0.0731	1385	0.7107
165	-6.2622	615	-2.5705	1150	-0.0802	1390	0.3254
170	-6.6775	620	-3.1238	1155	-0.0483	1395	-0.2322
175	-7.0928	625	-3.7691	1160	0.0032	1400	-1.0612
180	-7.5081	630	-4.5793	1165	0.0339	1405	-1.7715
185	-7.9234	635	-5.7012	1170	0.0249	1410	-2.6089
400	-8.0000	640	-6.5603	1175	-0.0296	1415	-3.0225
405	-7.4209	645	-7.4195	1180	-0.1170	1420	-3.3542
410	-6.6994	650	-8.0000	1185	-0.2141	1425	-3.7339
415	-5.9778	950	-7.9302	1190	-0.3069	1430	-4.1986
420	-5.2563	955	-7.6563	1195	-0.3968	1435	-4.7852
425	-4.4248	960	-7.3824	1200	-0.4881	1440	-5.6390
430	-3.7369	965	-7.1085	1205	-0.5881	1445	-6.2740
435	-3.0917	970	-6.8346	1210	-0.7019	1450	-6.9091
440	-2.5200	975	-6.5607	1215	-0.8299	1455	-7.5441
445	-2.0303	980	-6.2868	1220	-0.9729	1460	-8.0000

C' VALUE FOR SO2

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2415	-8.0000	2460	-1.8905	2505	-0.7097	2550	-4.5337
2420	-7.5698	2465	-1.5178	2510	-0.7297	2555	-4.9481
2425	-6.8815	2470	-1.2295	2515	-0.8391	2560	-5.4542
2430	-6.1933	2475	-1.0082	2520	-1.0472	2565	-6.2445
2435	-5.3530	2480	-0.8484	2525	-1.3607	2570	-6.8148
2440	-4.8602	2485	-0.7634	2530	-1.7720	2575	-7.3850
2445	-4.1286	2490	-0.7340	2535	-2.2957	2580	-7.9553
2450	-2.9922	2495	-0.7203	2540	-3.0566		
2455	-2.3525	2500	-0.7167	2545	-4.1073		

TABLE A11

C' VALUE FOR H_2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
0	-0.1812	240	2.9144	480	1.1549	720	-0.7673
5	0.0202	245	2.9820	485	1.0855	725	-0.8627
10	0.5738	250	3.0141	490	1.0370	730	-0.8810
15	1.3103	255	2.9369	495	1.0201	735	-0.8535
20	1.8408	260	2.7647	500	1.0326	740	-0.8190
25	2.1739	265	2.6901	505	1.0567	745	-0.8184
30	2.4195	270	2.6808	510	1.0674	750	-0.8670
35	2.6435	275	2.7956	515	1.0462	755	-0.9506
40	2.8203	280	2.8998	520	0.9866	760	-1.0473
45	2.9426	285	2.8561	525	0.9005	765	-1.1151
50	3.0497	290	2.7943	530	0.8133	770	-1.1266
55	3.1566	295	2.6376	535	0.7440	775	-1.1087
60	3.2306	300	2.5537	540	0.6976	780	-1.0190
65	3.3001	305	2.4656	545	0.6699	785	-0.9068
70	3.3654	310	2.3975	550	0.6545	790	-0.8274
75	3.4323	315	2.4036	555	0.6476	795	-1.0239
80	3.4937	320	2.4184	560	0.6505	800	-1.0421
85	3.5737	325	2.4813	565	0.6626	805	-1.1135
90	3.6597	330	2.4778	570	0.6724	810	-1.2245
95	3.6817	335	2.4619	575	0.6687	815	-1.4214
100	3.6664	340	2.4524	580	0.6410	820	-1.6264
105	3.6078	345	2.4104	585	0.5816	825	-1.7876
110	3.5217	350	2.4563	590	0.4967	830	-1.8697
115	3.4886	355	2.3814	595	0.3972	835	-1.8564
120	3.5312	360	2.2934	600	0.3012	840	-1.7853
125	3.5855	365	2.2038	605	0.2288	845	-1.7172
130	3.6005	370	2.1221	610	0.1913	850	-1.6768
135	3.6211	375	2.0643	615	0.1865	855	-1.6839
140	3.6278	380	2.0180	620	0.1997	860	-1.7372
145	3.6015	385	1.9674	625	0.2101	865	-1.8104
150	3.6091	390	1.8933	630	0.1967	870	-1.8849
155	3.5655	395	1.8008	635	0.1491	875	-1.9426
160	3.5014	400	1.7047	640	0.0685	880	-1.9849
165	3.4901	405	1.6289	645	-0.0292	885	-2.0341
170	3.4855	410	1.5929	650	-0.1222	890	-2.0990
175	3.4514	415	1.5910	655	-0.1926	895	-2.1701
180	3.3832	420	1.6015	660	-0.2366	900	-2.2294
185	3.3033	425	1.6018	665	-0.2629	905	-2.2558
190	3.2753	430	1.5815	670	-0.2760	910	-2.2557
195	3.3323	435	1.5451	675	-0.2748	915	-2.2620
200	3.4165	440	1.5096	680	-0.2532	920	-2.2932
205	3.4647	445	1.4836	685	-0.2122	925	-2.3605
210	3.4603	450	1.4633	690	-0.1691	930	-2.4517
215	3.4175	455	1.4456	695	-0.1534	935	-2.5284
220	3.3429	460	1.4164	700	-0.1891	940	-2.5687
225	3.2359	465	1.3699	705	-0.2863	945	-2.5663
230	3.0783	470	1.3099	710	-0.4382	950	-2.5417
235	2.9270	475	1.2347	715	-0.6116	955	-2.5218

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
960	-2.5128	1200	-0.8589	1440	2.1936	1680	2.8355
965	-2.5207	1205	-0.7779	1445	2.2215	1685	2.8975
970	-2.5498	1210	-0.6124	1450	2.3229	1690	2.9124
975	-2.6072	1215	-0.5062	1455	2.4535	1695	2.9340
980	-2.6971	1220	-0.4934	1460	2.5987	1700	2.9397
985	-2.7889	1225	-0.5213	1465	2.6517	1705	2.8687
990	-2.8701	1230	-0.6033	1470	2.6069	1710	2.7487
995	-2.8612	1235	-0.6177	1475	2.5501	1715	2.6408
1000	-2.7079	1240	-0.5314	1480	2.5073	1720	2.5413
1005	-2.2373	1245	-0.3988	1485	2.5454	1725	2.4900
1010	-2.1353	1250	-0.2325	1490	2.6488	1730	2.5476
1015	-2.0589	1255	-0.0223	1495	2.7779	1735	2.6212
1020	-2.0761	1260	0.1658	1500	2.9508	1740	2.6458
1025	-2.0976	1265	0.2794	1505	3.0812	1745	2.6382
1030	-2.1193	1270	0.3447	1510	3.1293	1750	2.5578
1035	-2.1870	1275	0.2978	1515	3.1473	1755	2.4572
1040	-2.1906	1280	0.2324	1520	3.1603	1760	2.4157
1045	-2.1541	1285	0.1817	1525	3.1636	1765	2.3863
1050	-2.0511	1290	0.1171	1530	3.1455	1770	2.3703
1055	-1.9449	1295	0.1042	1535	3.1314	1775	2.3307
1060	-1.8520	1300	0.1604	1540	3.1069	1780	2.2677
1065	-1.8165	1305	0.3383	1545	3.0830	1785	2.2263
1070	-1.8710	1310	0.6034	1550	3.0801	1790	2.1962
1075	-1.9205	1315	0.8261	1555	3.1026	1795	2.1682
1080	-2.0066	1320	0.9331	1560	3.1182	1800	2.0764
1085	-1.9934	1325	0.9452	1565	3.0153	1805	1.9140
1090	-1.8779	1330	0.9447	1570	2.7484	1810	1.7779
1095	-1.7336	1335	0.9885	1575	2.4735	1815	1.6895
1100	-1.5641	1340	1.0526	1580	2.2296	1820	1.6970
1105	-1.4584	1345	1.1066	1585	2.0281	1825	1.7978
1110	-1.4326	1350	1.1858	1590	1.9419	1830	1.8877
1115	-1.4831	1355	1.2809	1595	1.9389	1835	1.8981
1120	-1.5065	1360	1.4259	1600	2.0049	1840	1.8411
1125	-1.5260	1365	1.5778	1605	2.1689	1845	1.7072
1130	-1.5148	1370	1.6746	1610	2.3618	1850	1.5191
1135	-1.4096	1375	1.7412	1615	2.5624	1855	1.4207
1140	-1.3963	1380	1.7669	1620	2.7584	1860	1.3802
1145	-1.4136	1385	1.8424	1625	2.8735	1865	1.3628
1150	-1.3745	1390	1.9466	1630	2.9155	1870	1.3484
1155	-1.3824	1395	2.0051	1635	2.9490	1875	1.2677
1160	-1.2888	1400	2.0258	1640	2.9768	1880	1.2088
1165	-1.1300	1405	2.0099	1645	2.8228	1885	1.1792
1170	-1.0185	1410	1.9954	1650	2.8676	1890	1.1786
1175	-0.9049	1415	2.0521	1655	2.8259	1895	1.1889
1180	-0.8683	1420	2.1616	1660	2.7703	1900	1.1723
1185	-0.8533	1425	2.2325	1665	2.7396	1905	1.2219
1190	-0.8743	1430	2.2586	1670	2.7622	1910	1.2835
1195	-0.8807	1435	2.2371	1675	2.7882	1915	1.3027

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
1920	1.2724	2160	-1.1347	2400	-3.4784	2640	-1.2368
1925	1.1222	2165	-1.2487	2405	-3.5179	2645	-1.2071
1930	0.9763	2170	-1.3328	2410	-3.5954	2650	-1.1580
1935	0.9030	2175	-1.3925	2415	-3.6811	2655	-1.1502
1940	0.8984	2180	-1.4254	2420	-3.6902	2660	-1.1491
1945	0.9075	2185	-1.4462	2425	-3.7158	2665	-1.1583
1950	0.8475	2190	-1.4826	2430	-3.7440	2670	-1.2062
1955	0.7778	2195	-1.4922	2435	-3.8080	2675	-1.2342
1960	0.6639	2200	-1.4747	2440	-3.9454	2680	-1.2814
1965	0.5555	2205	-1.4477	2445	-4.0750	2685	-1.3596
1970	0.4399	2210	-1.4281	2450	-4.1232	2690	-1.3998
1975	0.3555	2215	-1.4645	2455	-4.0834	2695	-1.4457
1980	0.3809	2220	-1.5379	2460	-4.0210	2700	-1.4487
1985	0.4663	2225	-1.6089	2465	-3.9803	2705	-1.3074
1990	0.5763	2230	-1.6550	2470	-3.9693	2710	-1.1318
1995	0.5542	2235	-1.6587	2475	-3.9799	2715	-0.9833
2000	0.4549	2240	-1.6093	2480	-3.9665	2720	-0.8937
2005	0.3635	2245	-1.5565	2485	-3.9105	2725	-0.9452
2010	0.2992	2250	-1.5470	2490	-3.8659	2730	-1.1131
2015	0.3214	2255	-1.5633	2495	-3.8038	2735	-1.2956
2020	0.2997	2260	-1.6438	2500	-3.7031	2740	-1.4321
2025	0.1952	2265	-1.7559	2505	-3.6094	2745	-1.4390
2030	0.0734	2270	-1.8229	2510	-3.5248	2750	-1.4138
2035	-0.0526	2275	-1.8647	2515	-3.4132	2755	-1.3189
2040	-0.1049	2280	-1.9081	2520	-3.2989	2760	-1.2662
2045	-0.1447	2285	-1.9476	2525	-3.2165	2765	-1.1834
2050	-0.1788	2290	-2.0064	2530	-3.0805	2770	-1.1272
2055	-0.1817	2295	-2.0967	2535	-3.0800	2775	-1.0914
2060	-0.1573	2300	-2.1711	2540	-2.9658	2780	-1.0402
2065	-0.1355	2305	-2.2407	2545	-2.8356	2785	-1.0080
2070	-0.2217	2310	-2.3196	2550	-2.6892	2790	-1.0092
2075	-0.2999	2315	-2.3823	2555	-2.5946	2795	-1.0217
2080	-0.4285	2320	-2.4395	2560	-2.4680	2800	-1.0300
2085	-0.5174	2325	-2.5094	2565	-2.3255	2805	-1.0631
2090	-0.5425	2330	-2.5981	2570	-2.2386	2810	-1.0633
2095	-0.6269	2335	-2.6998	2575	-2.1120	2815	-1.0600
2100	-0.6940	2340	-2.8310	2580	-1.9958	2820	-1.0917
2105	-0.7630	2345	-2.9712	2585	-1.9284	2825	-1.1199
2110	-0.8325	2350	-3.0659	2590	-1.8215	2830	-1.1780
2115	-0.8799	2355	-3.1552	2595	-1.7405	2835	-1.2524
2120	-0.9237	2360	-3.2044	2600	-1.7019	2840	-1.3197
2125	-0.9430	2365	-3.2098	2605	-1.6182	2845	-1.3969
2130	-0.9490	2370	-3.2412	2610	-1.5500	2850	-1.4720
2135	-0.8967	2375	-3.2654	2615	-1.5154	2855	-1.5325
2140	-0.8642	2380	-3.3011	2620	-1.4337	2860	-1.5855
2145	-0.8769	2385	-3.3602	2625	-1.3733	2865	-1.6046
2150	-0.9212	2390	-3.4004	2630	-1.3477	2870	-1.6302
2155	-1.0212	2395	-3.4293	2635	-1.2816	2875	-1.6342

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
2880	-1.6003	3120	0.7843	3360	0.5952	3600	2.2863
2885	-1.5817	3125	0.6878	3365	0.6307	3605	2.3442
2890	-1.5099	3130	0.4881	3370	0.5729	3610	2.4226
2895	-1.4588	3135	0.1939	3375	0.4916	3615	2.4938
2900	-1.4607	3140	-0.1260	3380	0.4877	3620	2.5036
2905	-1.4726	3145	-0.4038	3385	0.5374	3625	2.4550
2910	-1.5401	3150	-0.6162	3390	0.5917	3630	2.4014
2915	-1.5617	3155	-0.7033	3395	0.6156	3635	2.3544
2920	-1.4417	3160	-0.6072	3400	0.5613	3640	2.3625
2925	-1.2813	3165	-0.3760	3405	0.5069	3645	2.4073
2930	-1.0989	3170	-0.1323	3410	0.4860	3650	2.4083
2935	-0.9890	3175	0.0608	3415	0.5262	3655	2.3863
2940	-0.9765	3180	0.1940	3420	0.6083	3660	2.3705
2945	-0.9608	3185	0.2359	3425	0.6230	3665	2.3947
2950	-0.9102	3190	0.2122	3430	0.6855	3670	2.4874
2955	-0.7801	3195	0.2445	3435	0.7186	3675	2.5942
2960	-0.6030	3200	0.3004	3440	0.7375	3680	2.6116
2965	-0.4232	3205	0.3824	3445	0.7834	3685	2.5623
2970	-0.2750	3210	0.5177	3450	0.7697	3690	2.4782
2975	-0.1549	3215	0.6033	3455	0.7498	3695	2.3890
2980	0.0616	3220	0.6400	3460	0.7579	3700	2.3658
2985	0.0694	3225	0.6460	3465	0.7765	3705	2.3850
2990	0.0736	3230	0.6386	3470	0.8418	3710	2.4360
2995	0.0717	3235	0.6019	3475	0.9196	3715	2.4871
3000	0.1036	3240	0.5836	3480	0.9842	3720	2.5590
3005	0.1845	3245	0.5731	3485	1.0502	3725	2.6496
3010	0.2599	3250	0.5299	3490	1.1139	3730	2.7477
3015	0.3217	3255	0.5235	3495	1.2044	3735	2.8995
3020	0.3621	3260	0.5294	3500	1.2824	3740	3.0062
3025	0.3685	3265	0.5445	3505	1.3438	3745	3.0534
3030	0.3313	3270	0.5840	3510	1.3947	3750	3.0079
3035	0.2441	3275	0.6286	3515	1.4195	3755	2.8611
3040	0.1339	3280	0.6362	3520	1.4521	3760	2.6608
3045	0.1127	3285	0.6145	3525	1.4787	3765	2.4672
3050	0.2022	3290	0.5761	3530	1.4903	3770	2.2972
3055	0.3100	3295	0.5270	3535	1.5011	3775	2.1281
3060	0.4004	3300	0.4846	3540	1.5363	3780	2.0523
3065	0.4447	3305	0.4544	3545	1.6117	3785	2.0368
3070	0.3886	3310	0.4538	3550	1.7140	3790	2.0972
3075	0.3323	3315	0.4161	3555	1.8143	3795	2.2719
3080	0.3469	3320	0.3936	3560	1.8965	3800	2.4604
3085	0.3633	3325	0.3947	3565	1.9480	3805	2.6112
3090	0.4400	3330	0.3409	3570	1.9574	3810	2.6919
3095	0.5638	3335	0.3039	3575	1.9688	3815	2.7361
3100	0.6559	3340	0.2707	3580	2.0002	3820	2.7702
3105	0.7300	3345	0.2557	3585	2.0637	3825	2.7963
3110	0.7886	3350	0.3515	3590	2.1363	3830	2.8127
3115	0.8096	3355	0.4930	3595	2.2138	3835	2.8175

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
3840	2.8054	4080	-0.0480	4320	-2.2748	4560	-1.7812
3845	2.7632	4085	-0.0594	4325	-2.4543	4565	-1.7303
3850	2.7557	4090	-0.1054	4330	-2.5521	4570	-1.6674
3855	2.7527	4095	-0.2084	4335	-2.6429	4575	-1.6190
3860	2.7065	4100	-0.2799	4340	-2.6534	4580	-1.6117
3865	2.6817	4105	-0.2851	4345	-2.6040	4585	-1.6904
3870	2.6119	4110	-0.4101	4350	-2.5259	4590	-1.7948
3875	2.5255	4115	-0.5642	4355	-2.4537	4595	-1.8709
3880	2.4680	4120	-0.6380	4360	-2.4754	4600	-1.9462
3885	2.4262	4125	-0.6410	4365	-2.5795	4605	-1.9896
3890	2.4004	4130	-0.5093	4370	-2.7782	4610	-1.9585
3895	2.3348	4135	-0.3854	4375	-3.0371	4615	-1.9314
3900	2.2415	4140	-0.3935	4380	-3.2926	4620	-1.8934
3905	2.0865	4145	-0.4981	4385	-3.5513	4625	-1.8665
3910	1.9026	4150	-0.6514	4390	-3.6189	4630	-1.8546
3915	1.8354	4155	-0.8405	4395	-3.5123	4635	-1.8362
3920	1.8106	4160	-1.0160	4400	-3.3512	4640	-1.8207
3925	1.7872	4165	-1.1354	4405	-3.1818	4645	-1.8340
3930	1.7687	4170	-1.1827	4410	-3.1300	4650	-1.9708
3935	1.6945	4175	-1.1794	4415	-3.2108	4655	-2.2230
3940	1.6097	4180	-1.0947	4420	-3.3498	4660	-2.5549
3945	1.5427	4185	-1.0332	4425	-3.5574	4665	-2.9104
3950	1.4509	4190	-1.0044	4430	-3.7446	4670	-3.0760
3955	1.3339	4195	-1.0331	4435	-3.7564	4675	-3.0220
3960	1.2150	4200	-1.1371	4440	-3.6491	4680	-2.9075
3965	1.0902	4205	-1.2312	4445	-3.4898	4685	-2.7605
3970	1.0034	4210	-1.3956	4450	-3.3607	4690	-2.5879
3975	0.9350	4215	-1.5400	4455	-3.2850	4695	-2.3978
3980	0.3475	4220	-1.6670	4460	-3.2740	4700	-2.2069
3985	0.7437	4225	-1.8652	4465	-3.3166	4705	-2.0652
3990	0.6354	4230	-2.0261	4470	-3.3505	4710	-1.9918
3995	0.5578	4235	-2.1237	4475	-3.3637	4715	-1.9610
4000	0.4968	4240	-2.0987	4480	-3.2713	4720	-1.9613
4005	0.5122	4245	-2.0102	4485	-3.1116	4725	-2.0232
4010	0.5500	4250	-1.9064	4490	-2.9310	4730	-2.0977
4015	0.5507	4255	-1.9116	4495	-2.7493	4735	-2.1689
4020	0.5383	4260	-2.0148	4500	-2.5970	4740	-2.2567
4025	0.4530	4265	-2.1396	4505	-2.4937	4745	-2.2269
4030	0.3475	4270	-2.3154	4510	-2.4121	4750	-2.0923
4035	0.2335	4275	-2.5129	4515	-2.3368	4755	-1.9772
4040	0.1392	4280	-2.7133	4520	-2.2675	4760	-1.8954
4045	0.1004	4285	-2.9431	4525	-2.1725	4765	-1.8721
4050	-0.0271	4290	-3.0428	4530	-2.0526	4770	-1.9508
4055	-0.1543	4295	-2.9565	4535	-1.9267	4775	-2.0404
4060	-0.2606	4300	-2.7965	4540	-1.8282	4780	-2.1519
4065	-0.3604	4305	-2.7101	4545	-1.7601	4785	-2.1996
4070	-0.2689	4310	-2.7825	4550	-1.7430	4790	-2.2079
4075	-0.1187	4315	-2.1281	4555	-1.7702	4795	-2.1740

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
4800	-2.1228	5040	-0.7216	5280	1.4514	5520	0.8750
4805	-2.0883	5045	-0.6994	5285	1.4270	5525	0.7804
4810	-2.0262	5050	-0.6446	5290	1.4035	5530	0.7032
4815	-1.9735	5055	-0.6109	5295	1.3592	5535	0.6731
4820	-1.9496	5060	-0.5699	5300	1.3440	5540	0.6372
4825	-1.9094	5065	-0.5378	5305	1.3459	5545	0.6141
4830	-1.8769	5070	-0.5293	5310	1.3618	5550	0.5692
4835	-1.8540	5075	-0.5118	5315	1.4228	5555	0.4426
4840	-1.8075	5080	-0.4455	5320	1.4984	5560	0.3017
4845	-1.7551	5085	-0.3259	5325	1.6324	5565	0.1976
4850	-1.7087	5090	-0.1429	5330	1.8170	5570	0.1022
4855	-1.6977	5095	0.0518	5335	1.9833	5575	0.0053
4860	-1.7196	5100	0.1805	5340	2.0737	5580	-0.1103
4865	-1.7996	5105	0.2580	5345	2.0026	5585	-0.2324
4870	-1.9347	5110	0.2652	5350	1.8365	5590	-0.3154
4875	-2.0480	5115	0.2526	5355	1.6397	5595	-0.3316
4880	-2.1313	5120	0.2650	5360	1.5105	5600	-0.3127
4885	-2.1162	5125	0.2998	5365	1.4770	5605	-0.3188
4890	-1.9964	5130	0.3825	5370	1.4995	5610	-0.3562
4895	-1.9319	5135	0.4740	5375	1.5981	5615	-0.3932
4900	-1.9029	5140	0.5743	5380	1.6983	5620	-0.4384
4905	-1.9137	5145	0.6771	5385	1.7494	5625	-0.5005
4910	-1.9554	5150	0.7611	5390	1.7691	5630	-0.5742
4915	-1.8788	5155	0.8454	5395	1.7738	5635	-0.6720
4920	-1.7774	5160	0.8949	5400	1.7719	5640	-0.8017
4925	-1.6724	5165	0.9252	5405	1.7662	5645	-0.8676
4930	-1.5862	5170	0.9732	5410	1.7548	5650	-0.8873
4935	-1.5612	5175	1.0286	5415	1.7173	5655	-0.8974
4940	-1.4869	5180	1.0920	5420	1.6871	5660	-0.8562
4945	-1.3837	5185	1.1340	5425	1.7242	5665	-0.8729
4950	-1.2600	5190	1.1587	5430	1.7985	5670	-0.9816
4955	-1.1770	5195	1.1751	5435	1.8625	5675	-1.0595
4960	-1.2091	5200	1.1881	5440	1.8882	5680	-1.1460
4965	-1.3207	5205	1.2115	5445	1.8360	5685	-1.1951
4970	-1.4417	5210	1.2762	5450	1.7371	5690	-1.1660
4975	-1.4593	5215	1.3556	5455	1.6493	5695	-1.1642
4980	-1.3271	5220	1.4626	5460	1.5947	5700	-1.2226
4985	-1.1473	5225	1.5203	5465	1.5057	5705	-1.2796
4990	-1.0126	5230	1.5608	5470	1.3886	5710	-1.3061
4995	-0.9516	5235	1.5800	5475	1.2943	5715	-1.3282
5000	-0.9540	5240	1.5940	5480	1.2026	5720	-1.2827
5005	-0.9498	5245	1.6573	5485	1.1664	5725	-1.2379
5010	-0.9200	5250	1.7306	5490	1.1828	5730	-1.2567
5015	-0.8852	5255	1.7761	5495	1.1511	5735	-1.2823
5020	-0.8348	5260	1.7430	5500	1.1018	5740	-1.3229
5025	-0.7910	5265	1.6531	5505	1.0582	5745	-1.3478
5030	-0.7758	5270	1.5449	5510	0.9817	5750	-1.4042
5035	-0.7393	5275	1.4752	5515	0.9207	5755	-1.4345

C' VALUE FOR H_2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
5760	-1.4501	6000	-3.0510	6240	-3.6892	6480	-2.9952
5765	-1.5426	6005	-2.9799	6245	-3.5292	6485	-2.9804
5770	-1.5757	6010	-2.9262	6250	-3.4135	6490	-2.9631
5775	-1.6509	6015	-2.8780	6255	-3.2729	6495	-2.9150
5780	-1.7601	6020	-2.8825	6260	-3.1545	6500	-2.8917
5785	-1.7475	6025	-2.9399	6265	-3.0808	6505	-2.8080
5790	-1.7471	6030	-2.9648	6270	-3.0437	6510	-2.7462
5795	-1.6807	6035	-2.9459	6275	-3.0735	6515	-2.6699
5800	-1.6324	6040	-2.9234	6280	-3.1559	6520	-2.5810
5805	-1.7177	6045	-2.8859	6285	-3.2438	6525	-2.4573
5810	-1.8331	6050	-2.8845	6290	-3.3310	6530	-2.3079
5815	-2.0050	6055	-2.9687	6295	-3.3990	6535	-2.1794
5820	-2.1013	6060	-3.0524	6300	-3.3832	6540	-2.0624
5825	-2.0825	6065	-3.1229	6305	-3.3894	6545	-1.9589
5830	-2.0526	6070	-3.2078	6310	-3.4428	6550	-1.8933
5835	-2.0389	6075	-3.2354	6315	-3.4864	6555	-1.8723
5840	-2.0690	6080	-3.3260	6320	-3.5912	6560	-1.8909
5845	-2.0776	6085	-3.4116	6325	-3.7099	6565	-1.8993
5850	-2.0697	6090	-3.4687	6330	-3.7305	6570	-1.8386
5855	-2.0709	6095	-3.5201	6335	-3.7546	6575	-1.7049
5860	-2.1350	6100	-3.5011	6340	-3.7941	6580	-1.5411
5865	-2.2453	6105	-3.5843	6345	-3.8032	6585	-1.4188
5870	-2.3595	6110	-3.6238	6350	-3.8671	6590	-1.3350
5875	-2.4143	6115	-3.6553	6355	-3.9228	6595	-1.2903
5880	-2.3557	6120	-3.7240	6360	-3.9073	6600	-1.2705
5885	-2.3393	6125	-3.7314	6365	-3.8213	6605	-1.2406
5890	-2.3489	6130	-3.9200	6370	-3.6965	6610	-1.2254
5895	-2.3935	6135	-4.2182	6375	-3.5644	6615	-1.1921
5900	-2.4614	6140	-4.5097	6380	-3.4629	6620	-1.1476
5905	-2.4734	6145	-4.8044	6385	-3.3858	6625	-1.1106
5910	-2.4674	6150	-4.7433	6390	-3.3538	6630	-1.0510
5915	-2.4937	6155	-4.5018	6395	-3.3630	6635	-0.9902
5920	-2.6043	6160	-4.4148	6400	-3.3923	6640	-0.8986
5925	-2.7309	6165	-4.2497	6405	-3.4927	6645	-0.8020
5930	-2.8902	6170	-4.0153	6410	-3.5769	6650	-0.7716
5935	-3.0170	6175	-3.8073	6415	-3.6556	6655	-0.7973
5940	-3.0463	6180	-3.6608	6420	-3.7219	6660	-0.8522
5945	-3.0961	6185	-3.5756	6425	-3.6760	6665	-0.8769
5950	-3.0726	6190	-3.5980	6430	-3.5758	6670	-0.8032
5955	-3.0056	6195	-3.6166	6435	-3.4598	6675	-0.6811
5960	-2.9444	6200	-3.6411	6440	-3.3814	6680	-0.5664
5965	-2.9159	6205	-3.6763	6445	-3.3548	6685	-0.4570
5970	-2.9462	6210	-3.6744	6450	-3.3902	6690	-0.4098
5975	-3.0184	6215	-3.7474	6455	-3.4396	6695	-0.4002
5980	-3.0960	6220	-3.8744	6460	-3.3918	6700	-0.3658
5985	-3.1167	6225	-3.9759	6465	-3.2910	6705	-0.3344
5990	-3.1174	6230	-3.9628	6470	-3.1629	6710	-0.2544
5995	-3.1139	6235	-3.8595	6475	-3.0484	6715	-0.1090

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
6720	0.0315	6960	0.6894	7200	1.3181	7440	0.0515
6725	0.1313	6965	0.7111	7205	1.4155	7445	-0.0663
6730	0.1650	6970	0.7474	7210	1.5003	7450	-0.1258
6735	0.1674	6975	0.7357	7215	1.5996	7455	-0.1273
6740	0.1752	6980	0.7378	7220	1.6975	7460	-0.0923
6745	0.2167	6985	0.7248	7225	1.7811	7465	-0.0500
6750	0.2905	6990	0.6909	7230	1.8699	7470	-0.0044
6755	0.3583	6995	0.6918	7235	1.8685	7475	0.0332
6760	0.3791	7000	0.7169	7240	1.8037	7480	0.0373
6765	0.3377	7005	0.7398	7245	1.6796	7485	0.0497
6770	0.2823	7010	0.7659	7250	1.5376	7490	0.0693
6775	0.2339	7015	0.7719	7255	1.4114	7495	0.1115
6780	0.2325	7020	0.7478	7260	1.3161	7500	0.1668
6785	0.3497	7025	0.7474	7265	1.2558	7505	0.2004
6790	0.5023	7030	0.7553	7270	1.2253	7510	0.2092
6795	0.6087	7035	0.7980	7275	1.2508	7515	0.1640
6800	0.6732	7040	0.8667	7280	1.3163	7520	0.0995
6805	0.6506	7045	0.8921	7285	1.4383	7525	0.0224
6810	0.5871	7050	0.8905	7290	1.5988	7530	-0.0983
6815	0.5496	7055	0.8936	7295	1.7430	7535	-0.2420
6820	0.5164	7060	0.8921	7300	1.8374	7540	-0.3874
6825	0.4552	7065	0.9393	7305	1.8591	7545	-0.4794
6830	0.4046	7070	0.9821	7310	1.8598	7550	-0.5028
6835	0.3669	7075	0.9696	7315	1.8277	7555	-0.4573
6840	0.2945	7080	0.9787	7320	1.7929	7560	-0.3756
6845	0.2565	7085	0.9841	7325	1.8132	7565	-0.3220
6850	0.1979	7090	1.0548	7330	1.8258	7570	-0.3010
6855	0.1417	7095	1.1648	7335	1.8543	7575	-0.3421
6860	0.1459	7100	1.2342	7340	1.9203	7580	-0.4472
6865	0.1603	7105	1.3103	7345	1.9137	7585	-0.5660
6870	0.2321	7110	1.3090	7350	1.8697	7590	-0.6560
6875	0.3198	7115	1.2764	7355	1.7893	7595	-0.6686
6880	0.4272	7120	1.2694	7360	1.6736	7600	-0.6241
6885	0.5379	7125	1.2528	7365	1.5887	7605	-0.5759
6890	0.5917	7130	1.2951	7370	1.5199	7610	-0.5929
6895	0.5977	7135	1.3662	7375	1.4920	7615	-0.6651
6900	0.5479	7140	1.3821	7380	1.4607	7620	-0.7538
6905	0.5184	7145	1.3688	7385	1.4013	7625	-0.8310
6910	0.5177	7150	1.3387	7390	1.3084	7630	-0.8275
6915	0.5543	7155	1.3547	7395	1.1831	7635	-0.8259
6920	0.5948	7160	1.4353	7400	1.0698	7640	-0.8523
6925	0.6026	7165	1.5294	7405	0.9747	7645	-0.8954
6930	0.6161	7170	1.5617	7410	0.8584	7650	-0.9631
6935	0.5950	7175	1.4882	7415	0.7723	7655	-1.0003
6940	0.5957	7180	1.3935	7420	0.6534	7660	-1.0299
6945	0.6117	7185	1.2927	7425	0.5116	7665	-1.0615
6950	0.6189	7190	1.2499	7430	0.3601	7670	-1.1136
6955	0.6695	7195	1.2684	7435	0.1920	7675	-1.1917

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
7680	-1.2607	7920	-3.2658	8160	-2.0501	8400	-1.2358
7685	-1.3097	7925	-3.3804	8165	-2.0157	8405	-1.1408
7690	-1.3247	7930	-3.5208	8170	-1.9539	8410	-1.0532
7695	-1.3361	7935	-3.6808	8175	-1.9083	8415	-0.9992
7700	-1.3472	7940	-3.8519	8180	-1.8867	8420	-1.0228
7705	-1.3440	7945	-3.9173	8185	-1.8695	8425	-1.0750
7710	-1.3975	7950	-3.9464	8190	-1.8926	8430	-1.1285
7715	-1.5031	7955	-3.9351	8195	-1.8978	8435	-1.1560
7720	-1.6398	7960	-3.8324	8200	-1.9072	8440	-1.1115
7725	-1.7914	7965	-3.7503	8205	-1.9070	8445	-1.0570
7730	-1.8962	7970	-3.7687	8210	-1.8690	8450	-1.0217
7735	-1.9073	7975	-3.8546	8215	-1.7832	8455	-1.0038
7740	-1.8532	7980	-4.0527	8220	-1.6506	8460	-1.0159
7745	-1.8097	7985	-4.2924	8225	-1.5626	8465	-1.0808
7750	-1.7846	7990	-4.4755	8230	-1.5017	8470	-1.1500
7755	-1.8067	7995	-4.5014	8235	-1.4799	8475	-1.1618
7760	-1.9020	8000	-4.3497	8240	-1.4978	8480	-1.1736
7765	-2.0791	8005	-4.0053	8245	-1.4739	8485	-1.1780
7770	-2.2674	8010	-3.9150	8250	-1.4260	8490	-1.1916
7775	-2.4321	8015	-3.9090	8255	-1.3968	8495	-1.2840
7780	-2.5341	8020	-3.9456	8260	-1.3911	8500	-1.3486
7785	-2.5431	8025	-3.9489	8265	-1.4190	8505	-1.3178
7790	-2.5783	8030	-3.9853	8270	-1.4788	8510	-1.2495
7795	-2.6134	8035	-3.9860	8275	-1.5357	8515	-1.1526
7800	-2.5846	8040	-4.0059	8280	-1.5726	8520	-1.1067
7805	-2.5087	8045	-4.0570	8285	-1.5777	8525	-1.1336
7810	-2.4441	8050	-4.0754	8290	-1.5332	8530	-1.1710
7815	-2.4012	8055	-4.0837	8295	-1.4385	8535	-1.2055
7820	-2.4571	8060	-4.0709	8300	-1.3399	8540	-1.1921
7825	-2.5694	8065	-4.0609	8305	-1.2606	8545	-1.1551
7830	-2.6774	8070	-3.9349	8310	-1.2255	8550	-1.1369
7835	-2.7645	8075	-3.7690	8315	-1.2344	8555	-1.1210
7840	-2.8964	8080	-3.6130	8320	-1.2268	8560	-1.1314
7845	-2.9762	8085	-3.4684	8325	-1.2020	8565	-1.1413
7850	-2.9754	8090	-3.3967	8330	-1.1812	8570	-1.1284
7855	-2.8633	8095	-3.2429	8335	-1.1583	8575	-1.1215
7860	-2.7881	8100	-3.0787	8340	-1.1570	8580	-1.1006
7865	-2.7935	8105	-2.9151	8345	-1.2054	8585	-1.1009
7870	-2.9067	8110	-2.7695	8350	-1.2319	8590	-1.0901
7875	-3.0354	8115	-2.7110	8355	-1.2622	8595	-1.0485
7880	-3.1019	8120	-2.6564	8360	-1.2879	8600	-0.9921
7885	-3.1016	8125	-2.6147	8365	-1.2835	8605	-0.8816
7890	-3.0746	8130	-2.5360	8370	-1.3272	8610	-0.7763
7895	-3.1460	8135	-2.4059	8375	-1.3664	8615	-0.6930
7900	-3.2617	8140	-2.2978	8380	-1.3884	8620	-0.6244
7905	-3.3269	8145	-2.1854	8385	-1.4100	8625	-0.5831
7910	-3.3442	8150	-2.1156	8390	-1.3683	8630	-0.5556
7915	-3.2819	8155	-2.0899	8395	-1.3080	8635	-0.5009

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
8640	-0.4097	8880	0.5808	9120	-1.2032	9360	-2.9042
8645	-0.3050	8885	0.5650	9125	-1.1965	9365	-3.0708
8650	-0.1616	8890	0.5246	9130	-1.1929	9370	-3.2315
8655	-0.0558	8895	0.5586	9135	-1.1556	9375	-3.3218
8660	-0.0061	8900	0.6055	9140	-1.1794	9380	-3.3626
8665	0.0314	8905	0.6360	9145	-1.2390	9385	-3.3695
8670	0.0201	8910	0.6737	9150	-1.3134	9390	-3.4587
8675	0.0337	8915	0.6267	9155	-1.4104	9395	-3.5631
8680	0.0695	8920	0.5656	9160	-1.4922	9400	-3.6065
8685	0.0985	8925	0.5352	9165	-1.5037	9405	-3.6277
8690	0.1357	8930	0.4868	9170	-1.4742	9410	-3.5866
8695	0.1406	8935	0.4455	9175	-1.4820	9415	-3.6487
8700	0.1529	8940	0.3754	9180	-1.5228	9420	-3.8281
8705	0.1885	8945	0.2792	9185	-1.6500	9425	-4.0460
8710	0.2263	8950	0.2035	9190	-1.7488	9430	-4.0380
8715	0.2722	8955	0.1116	9195	-1.7480	9435	-3.7419
8720	0.3575	8960	-0.0045	9200	-1.6859	9440	-3.4772
8725	0.4079	8965	-0.1001	9205	-1.5721	9445	-3.3053
8730	0.4469	8970	-0.1921	9210	-1.5343	9450	-3.3228
8735	0.3991	8975	-0.2621	9215	-1.5476	9455	-3.5127
8740	0.3184	8980	-0.2954	9220	-1.6031	9460	-3.8038
8745	0.2206	8985	-0.3604	9225	-1.7029	9465	-4.2514
8750	0.1564	8990	-0.4452	9230	-1.7905	9470	-4.5804
8755	0.1294	8995	-0.5171	9235	-1.8831	9475	-4.5544
8760	0.1034	9000	-0.5865	9240	-1.8878	9480	-4.5713
8765	0.0673	9005	-0.6313	9245	-1.8372	9485	-4.6920
8770	0.0029	9010	-0.6487	9250	-1.8162	9490	-4.8163
8775	-0.0588	9015	-0.6574	9255	-1.8256	9495	-4.8501
8780	-0.0836	9020	-0.6422	9260	-1.9236	9500	-4.8011
8785	-0.0424	9025	-0.6147	9265	-2.0376	9505	-4.5647
8790	0.0267	9030	-0.6052	9270	-2.0825	9510	-4.6219
8795	0.1478	9035	-0.5969	9275	-2.0945	9515	-4.8562
8800	0.3468	9040	-0.5977	9280	-2.0993	9520	-5.1914
8805	0.5413	9045	-0.6579	9285	-2.1896	9525	-5.7005
8810	0.7077	9050	-0.7036	9290	-2.3027	9530	-5.7670
8815	0.7386	9055	-0.7265	9295	-2.3798	9535	-5.4617
8820	0.6075	9060	-0.7657	9300	-2.4116	9540	-5.2340
8825	0.3988	9065	-0.7476	9305	-2.3392	9545	-5.1208
8830	0.1846	9070	-0.7263	9310	-2.3184	9550	-5.0644
8835	0.0665	9075	-0.7339	9315	-2.3155	9555	-5.0739
8840	0.0539	9080	-0.7209	9320	-2.3080	9560	-5.1788
8845	0.1505	9085	-0.7045	9325	-2.3553	9565	-5.3526
8850	0.3267	9090	-0.6978	9330	-2.4219	9570	-5.6469
8855	0.4598	9095	-0.6960	9335	-2.5069	9575	-5.8194
8860	0.5379	9100	-0.7640	9340	-2.6066	9580	-5.8408
8865	0.5810	9105	-0.8850	9345	-2.6786	9585	-5.7263
8870	0.5851	9110	-1.0211	9350	-2.7094	9590	-5.5654
8875	0.5739	9115	-1.1685	9355	-2.7788	9595	-5.5283

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
9600	-5.5125	9840	-3.1753	10080	-3.0211	10320	-1.3276
9605	-5.4942	9845	-3.0810	10085	-2.9846	10325	-1.2547
9610	-5.4902	9850	-3.0792	10090	-2.9500	10330	-1.1312
9615	-5.5985	9855	-3.0675	10095	-2.8264	10335	-0.9723
9620	-5.9373	9860	-3.0913	10100	-2.7190	10340	-0.7965
9625	-6.1143	9865	-3.0959	10105	-2.7057	10345	-0.6925
9630	-6.5729	9870	-3.0159	10110	-2.6532	10350	-0.6449
9635	-6.1453	9875	-2.9528	10115	-2.6247	10355	-0.6368
9640	-5.7287	9880	-2.8692	10120	-2.5861	10360	-0.6328
9645	-5.4382	9885	-2.8246	10125	-2.5280	10365	-0.6503
9650	-5.2161	9890	-2.7110	10130	-2.5268	10370	-0.6500
9655	-5.1721	9895	-2.5400	10135	-2.4800	10375	-0.6527
9660	-5.0168	9900	-2.3937	10140	-2.3716	10380	-0.6316
9665	-4.8174	9905	-2.2799	10145	-2.2297	10385	-0.5527
9670	-4.6582	9910	-2.2794	10150	-2.0726	10390	-0.4624
9675	-4.4759	9915	-2.3728	10155	-1.9632	10395	-0.4202
9680	-4.3208	9920	-2.4972	10160	-1.8709	10400	-0.3970
9685	-4.2009	9925	-2.6596	10165	-1.7544	10405	-0.4079
9690	-4.0669	9930	-2.7850	10170	-1.6283	10410	-0.4306
9695	-3.9462	9935	-2.8225	10175	-1.5185	10415	-0.4454
9700	-3.8890	9940	-2.8443	10180	-1.4807	10420	-0.4352
9705	-3.7572	9945	-2.7861	10185	-1.5093	10425	-0.4592
9710	-3.6198	9950	-2.7905	10190	-1.5612	10430	-0.5078
9715	-3.4448	9955	-2.7637	10195	-1.5542	10435	-0.5107
9720	-3.2444	9960	-2.7097	10200	-1.4693	10440	-0.5239
9725	-3.1556	9965	-2.6686	10205	-1.3401	10445	-0.4572
9730	-3.0826	9970	-2.5763	10210	-1.2031	10450	-0.3372
9735	-3.0728	9975	-2.5127	10215	-1.1485	10455	-0.2717
9740	-3.1429	9980	-2.5399	10220	-1.1473	10460	-0.1938
9745	-3.1816	9985	-2.6477	10225	-1.1692	10465	-0.1735
9750	-3.1276	9990	-2.8155	10230	-1.2003	10470	-0.2161
9755	-2.9983	9995	-2.9931	10235	-1.1651	10475	-0.2484
9760	-2.8298	10000	-3.0699	10240	-1.0637	10480	-0.3011
9765	-2.6909	10005	-3.0338	10245	-0.9679	10485	-0.3003
9770	-2.6752	10010	-3.0261	10250	-0.8965	10490	-0.2165
9775	-2.7387	10015	-3.0428	10255	-0.8603	10495	-0.1511
9780	-2.8795	10020	-3.1213	10260	-0.8928	10500	-0.1365
9785	-3.0367	10025	-3.2751	10265	-0.9454	10505	-0.1921
9790	-3.1487	10030	-3.4031	10270	-1.0129	10510	-0.2745
9795	-3.1190	10035	-3.5863	10275	-1.0956	10515	-0.2771
9800	-3.0156	10040	-3.6839	10280	-1.1511	10520	-0.2079
9805	-2.9613	10045	-3.6814	10285	-1.2139	10525	-0.1183
9810	-2.9140	10050	-3.6658	10290	-1.2396	10530	-0.0640
9815	-2.9915	10055	-3.4679	10295	-1.2673	10535	-0.0925
9820	-3.1025	10060	-3.3080	10300	-1.2955	10540	-0.1183
9825	-3.2070	10065	-3.1545	10305	-1.3041	10545	-0.1304
9830	-3.2590	10070	-3.0139	10310	-1.3326	10550	-0.1392
9835	-3.2280	10075	-3.0036	10315	-1.3359	10555	-0.0926

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
10560	-0.0478	10800	-1.1665	11040	-1.2002	11280	-3.1574
10565	-0.0227	10805	-1.1424	11045	-1.2692	11285	-3.0905
10570	0.0177	10810	-1.1128	11050	-1.3419	11290	-3.1861
10575	0.0401	10815	-1.1085	11055	-1.3403	11295	-3.3799
10580	0.0404	10820	-1.1048	11060	-1.2988	11300	-3.5730
10585	0.0874	10825	-1.1489	11065	-1.1947	11305	-3.7820
10590	0.1493	10830	-1.2112	11070	-1.0029	11310	-3.8224
10595	0.1512	10835	-1.2573	11075	-0.8295	11315	-3.7847
10600	0.1534	10840	-1.2700	11080	-0.7039	11320	-3.7525
10605	0.0950	10845	-1.2548	11085	-0.6416	11325	-3.7628
10610	-0.0296	10850	-1.2573	11090	-0.6214	11330	-3.7344
10615	-0.1489	10855	-1.2843	11095	-0.6387	11335	-3.7182
10620	-0.2654	10860	-1.3043	11100	-0.6690	11340	-3.7536
10625	-0.3741	10865	-1.3358	11105	-0.6673	11345	-3.7424
10630	-0.4674	10870	-1.2830	11110	-0.6801	11350	-3.8073
10635	-0.4887	10875	-1.2053	11115	-0.6778	11355	-3.8745
10640	-0.4761	10880	-1.1132	11120	-0.6581	11360	-3.9514
10645	-0.3783	10885	-0.9810	11125	-0.7090	11365	-4.1133
10650	-0.1797	10890	-0.9083	11130	-0.7799	11370	-4.2154
10655	0.0289	10895	-0.8525	11135	-0.8319	11375	-4.3096
10660	0.2048	10900	-0.8496	11140	-0.8738	11380	-4.3514
10665	0.2932	10905	-0.8660	11145	-0.9123	11385	-4.3748
10670	0.3509	10910	-0.8486	11150	-0.9340	11390	-4.5165
10675	0.3408	10915	-0.8333	11155	-0.9993	11395	-4.6868
10680	0.3200	10920	-0.8123	11160	-1.1041	11400	-4.8253
10685	0.3526	10925	-0.8288	11165	-1.1964	11405	-4.9403
10690	0.3487	10930	-0.8501	11170	-1.3394	11410	-4.9352
10695	0.3800	10935	-0.8131	11175	-1.4823	11415	-4.9954
10700	0.4055	10940	-0.7490	11180	-1.5989	11420	-5.1703
10705	0.3578	10945	-0.6845	11185	-1.7308	11425	-5.3415
10710	0.2909	10950	-0.6513	11190	-1.8317	11430	-5.4462
10715	0.2137	10955	-0.7208	11195	-1.9372	11435	-5.4937
10720	0.1407	10960	-0.8005	11200	-2.1201	11440	-5.4519
10725	0.0771	10965	-0.8438	11205	-2.3207	11445	-5.4889
10730	0.0244	10970	-0.8835	11210	-2.5255	11450	-5.7043
10735	-0.0615	10975	-0.8402	11215	-2.7657	11455	-5.9860
10740	-0.1503	10980	-0.7846	11220	-2.9086	11460	-6.4149
10745	-0.2530	10985	-0.7422	11225	-2.9959	11465	-6.8287
10750	-0.3686	10990	-0.7010	11230	-3.1038	11470	-6.6025
10755	-0.4845	10995	-0.6819	11235	-3.1739	11475	-6.2881
10760	-0.5994	11000	-0.6880	11240	-3.2620	11480	-6.0586
10765	-0.6928	11005	-0.6822	11245	-3.3152	11485	-5.9478
10770	-0.7726	11010	-0.6683	11250	-3.3272	11490	-6.0163
10775	-0.8515	11015	-0.6827	11255	-3.2894	11495	-6.1264
10780	-0.9362	11020	-0.6998	11260	-3.2325	11500	-6.3798
10785	-1.0397	11025	-0.7983	11265	-3.2389	11505	-6.5110
10790	-1.1208	11030	-0.9223	11270	-3.2154	11510	-6.6422
10795	-1.1493	11035	-1.0680	11275	-3.1722	11515	-6.7734

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
11520	-6.9046	11760	-2.7175	12000	-1.7207	12240	-1.0714
11525	-7.0359	11765	-2.7841	12005	-1.6893	12245	-1.0542
11530	-7.1671	11770	-2.8210	12010	-1.6496	12250	-1.0579
11535	-7.2983	11775	-2.8220	12015	-1.5994	12255	-1.1101
11540	-7.4295	11780	-2.7847	12020	-1.5847	12260	-1.1748
11545	-7.5607	11785	-2.7994	12025	-1.5897	12265	-1.2521
11550	-7.9419	11790	-2.8397	12030	-1.6099	12270	-1.3314
11555	-8.3688	11795	-2.9935	12035	-1.6241	12275	-1.3848
11560	-7.0920	11800	-3.1212	12040	-1.6075	12280	-1.4153
11565	-6.1009	11805	-3.1513	12045	-1.5782	12285	-1.4741
11570	-5.5830	11810	-3.1296	12050	-1.5392	12290	-1.5152
11575	-5.2579	11815	-2.9961	12055	-1.4904	12295	-1.5978
11580	-5.0834	11820	-2.9395	12060	-1.4373	12300	-1.7196
11585	-5.1056	11825	-2.8723	12065	-1.3879	12305	-1.7925
11590	-5.2344	11830	-2.8098	12070	-1.3316	12310	-1.8652
11595	-5.1786	11835	-2.7851	12075	-1.3360	12315	-1.9267
11600	-5.0282	11840	-2.7321	12080	-1.4025	12320	-1.9649
11605	-4.8109	11845	-2.7001	12085	-1.5084	12325	-2.0443
11610	-4.6420	11850	-2.6661	12090	-1.6387	12330	-2.1376
11615	-4.6779	11855	-2.6107	12095	-1.6836	12335	-2.2177
11620	-4.6975	11860	-2.5305	12100	-1.6743	12340	-2.2956
11625	-4.5550	11865	-2.4588	12105	-1.6769	12345	-2.3373
11630	-4.4013	11870	-2.3692	12110	-1.6966	12350	-2.3622
11635	-4.2154	11875	-2.2492	12115	-1.7563	12355	-2.4038
11640	-4.1050	11880	-2.1824	12120	-1.7966	12360	-2.4422
11645	-3.9551	11885	-2.1507	12125	-1.7317	12365	-2.4846
11650	-3.7680	11890	-2.1394	12130	-1.5876	12370	-2.5459
11655	-3.6154	11895	-2.1832	12135	-1.3855	12375	-2.5863
11660	-3.4820	11900	-2.2450	12140	-1.1593	12380	-2.6434
11665	-3.4758	11905	-2.2493	12145	-1.0022	12385	-2.6830
11670	-3.4607	11910	-2.2377	12150	-0.9612	12390	-2.6846
11675	-3.3988	11915	-2.2385	12155	-1.0693	12395	-2.6912
11680	-3.3012	11920	-2.1734	12160	-1.2620	12400	-2.6594
11685	-3.1415	11925	-2.1597	12165	-1.4807	12405	-2.6645
11690	-3.0253	11930	-2.1609	12170	-1.6751	12410	-2.6487
11695	-2.9222	11935	-2.0867	12175	-1.7804	12415	-2.5691
11700	-2.8394	11940	-2.0515	12180	-1.8200	12420	-2.4884
11705	-2.7932	11945	-1.9962	12185	-1.7499	12425	-2.3527
11710	-2.7797	11950	-1.9406	12190	-1.5670	12430	-2.2621
11715	-2.7976	11955	-1.9530	12195	-1.3743	12435	-2.2743
11720	-2.8092	11960	-1.9682	12200	-1.2439	12440	-2.2476
11725	-2.7905	11965	-2.0178	12205	-1.1588	12445	-2.2303
11730	-2.7043	11970	-2.0710	12210	-1.1149	12450	-2.1964
11735	-2.6252	11975	-2.0776	12215	-1.1148	12455	-2.1496
11740	-2.5730	11980	-2.0457	12220	-1.0906	12460	-2.1304
11745	-2.5476	11985	-1.9355	12225	-1.0861	12465	-2.1569
11750	-2.5970	11990	-1.8605	12230	-1.1093	12470	-2.1683
11755	-2.6429	11995	-1.7852	12235	-1.0847	12475	-2.1530

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
12480	-2.1365	12720	-3.2122	12960	-8.6529	13200	-7.8713
12485	-2.0897	12725	-3.4561	12965	-8.7824	13205	-7.7265
12490	-2.0923	12730	-3.6838	12970	-8.9118	13210	-7.5816
12495	-2.1267	12735	-3.8338	12975	-9.0413	13215	-7.4368
12500	-2.1941	12740	-3.9046	12980	-9.1707	13220	-7.2919
12505	-2.2762	12745	-4.0929	12985	-9.3002	13225	-7.1471
12510	-2.3215	12750	-4.3552	12990	-9.4297	13230	-7.0022
12515	-2.3569	12755	-4.6098	12995	-9.5591	13235	-6.8574
12520	-2.3726	12760	-4.8878	13000	-9.6886	13240	-6.7125
12525	-2.3992	12765	-4.9972	13005	-9.8180	13245	-6.5677
12530	-2.4136	12770	-5.0897	13010	-9.9475	13250	-6.4228
12535	-2.3742	12775	-5.1819	13015	-10.0770	13255	-6.2780
12540	-2.2423	12780	-5.2493	13020	-10.2065	13260	-6.1331
12545	-2.0783	12785	-5.3592	13025	-10.3360	13265	-5.9883
12550	-1.9591	12790	-5.4721	13030	-10.4655	13270	-5.8434
12555	-1.8949	12795	-5.5599	13035	-10.5950	13275	-5.6986
12560	-1.9383	12800	-5.5613	13040	-10.7245	13280	-5.5537
12565	-2.0752	12805	-5.4614	13045	-10.8540	13285	-5.4089
12570	-2.2512	12810	-5.2616	13050	-10.9835	13290	-5.2640
12575	-2.4541	12815	-5.1237	13055	-11.1130	13295	-5.1192
12580	-2.6506	12820	-5.0902	13060	-11.2425	13300	-4.9743
12585	-2.8067	12825	-5.0818	13065	-11.3720	13305	-4.7853
12590	-2.8574	12830	-5.1220	13070	-11.5015	13310	-4.6276
12595	-2.7901	12835	-5.2792	13075	-11.4924	13315	-4.4743
12600	-2.6216	12840	-5.3872	13080	-11.3476	13320	-4.3949
12605	-2.4060	12845	-5.4629	13085	-11.2027	13325	-4.3965
12610	-2.2524	12850	-5.5365	13090	-11.0579	13330	-4.4788
12615	-2.1698	12855	-5.4766	13095	-10.9130	13335	-4.6282
12620	-2.1278	12860	-5.5520	13100	-10.7682	13340	-4.8132
12625	-2.1038	12865	-5.7170	13105	-10.6233	13345	-4.9466
12630	-2.1139	12870	-6.0034	13110	-10.4785	13350	-4.9381
12635	-2.1060	12875	-6.2934	13115	-10.3336	13355	-4.8432
12640	-2.0873	12880	-6.5816	13120	-10.1888	13360	-4.7264
12645	-2.1014	12885	-6.7111	13125	-10.0439	13365	-4.6342
12650	-2.0499	12890	-6.8405	13130	-9.8992	13370	-4.4883
12655	-2.0154	12895	-6.9700	13135	-9.7544	13375	-4.3480
12660	-1.9920	12900	-7.0994	13140	-9.6095	13380	-4.2424
12665	-1.9883	12905	-7.2289	13145	-9.4647	13385	-4.1553
12670	-2.0677	12910	-7.3583	13150	-9.3198	13390	-4.1234
12675	-2.1657	12915	-7.4878	13155	-9.1749	13395	-4.1334
12680	-2.2940	12920	-7.6173	13160	-9.0301	13400	-4.0693
12685	-2.4044	12925	-7.7467	13165	-8.8853	13405	-3.9846
12690	-2.4715	12930	-7.8762	13170	-8.7404	13410	-3.9327
12695	-2.5209	12935	-8.0056	13175	-8.5956	13415	-3.8731
12700	-2.5711	12940	-8.1351	13180	-8.4507	13420	-3.7905
12705	-2.6539	12945	-8.2645	13185	-8.3059	13425	-3.7085
12710	-2.7723	12950	-8.3940	13190	-8.1610	13430	-3.6036
12715	-2.9634	12955	-8.5235	13195	-8.0162	13435	-3.5197

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
13440	-3.5289	13680	-1.2121	13920	-0.9412	14160	-1.9941
13445	-3.5123	13685	-1.2156	13925	-0.9678	14165	-1.9499
13450	-3.3943	13690	-1.2090	13930	-0.9991	14170	-1.9277
13455	-3.2240	13695	-1.2139	13935	-1.0494	14175	-1.9157
13460	-3.0505	13700	-1.1827	13940	-1.1302	14180	-1.9599
13465	-2.9175	13705	-1.1431	13945	-1.2590	14185	-2.0141
13470	-2.8605	13710	-1.1432	13950	-1.4233	14190	-2.0187
13475	-2.8163	13715	-1.1747	13955	-1.5992	14195	-2.0436
13480	-2.7655	13720	-1.2269	13960	-1.7714	14200	-2.0504
13485	-2.7264	13725	-1.2435	13965	-1.9028	14205	-2.1010
13490	-2.6882	13730	-1.1822	13970	-1.9952	14210	-2.1587
13495	-2.6885	13735	-1.0976	13975	-2.0440	14215	-2.1415
13500	-2.6430	13740	-1.0516	13980	-2.0500	14220	-2.0313
13505	-2.5743	13745	-1.0266	13985	-2.0681	14225	-1.8741
13510	-2.4456	13750	-1.0715	13990	-2.1030	14230	-1.7627
13515	-2.3017	13755	-1.1101	13995	-2.1541	14235	-1.6906
13520	-2.2448	13760	-1.1043	14000	-2.2225	14240	-1.6868
13525	-2.1719	13765	-1.1055	14005	-2.2764	14245	-1.6974
13530	-2.1494	13770	-1.1001	14010	-2.3081	14250	-1.7025
13535	-2.1401	13775	-1.1024	14015	-2.3320	14255	-1.7104
13540	-2.0956	13780	-1.1160	14020	-2.3535	14260	-1.6862
13545	-2.1025	13785	-1.0883	14025	-2.3980	14265	-1.6843
13550	-2.0749	13790	-1.0746	14030	-2.4621	14270	-1.6685
13555	-2.0359	13795	-1.0569	14035	-2.5113	14275	-1.6958
13560	-1.9697	13800	-1.0336	14040	-2.5471	14280	-1.7216
13565	-1.8637	13805	-1.0062	14045	-2.5382	14285	-1.7092
13570	-1.7893	13810	-0.9901	14050	-2.5060	14290	-1.6895
13575	-1.7288	13815	-1.0002	14055	-2.4525	14295	-1.6110
13580	-1.7116	13820	-1.0558	14060	-2.3871	14300	-1.5836
13585	-1.7417	13825	-1.1944	14065	-2.3238	14305	-1.6081
13590	-1.7760	13830	-1.3615	14070	-2.2655	14310	-1.6905
13595	-1.8218	13835	-1.5049	14075	-2.2369	14315	-1.8453
13600	-1.8525	13840	-1.6034	14080	-2.2399	14320	-1.9987
13605	-1.8785	13845	-1.6630	14085	-2.2724	14325	-2.1305
13610	-1.9282	13850	-1.6291	14090	-2.3092	14330	-2.2354
13615	-1.9501	13855	-1.5692	14095	-2.3522	14335	-2.3112
13620	-1.9530	13860	-1.4728	14100	-2.3796	14340	-2.3189
13625	-1.9066	13865	-1.3006	14105	-2.3700	14345	-2.2844
13630	-1.8088	13870	-1.1289	14110	-2.3377	14350	-2.1477
13635	-1.7525	13875	-0.9655	14115	-2.2718	14355	-1.9411
13640	-1.7281	13880	-0.8559	14120	-2.1896	14360	-1.7699
13645	-1.6901	13885	-0.7959	14125	-2.1454	14365	-1.6468
13650	-1.6417	13890	-0.8011	14130	-2.1377	14370	-1.5784
13655	-1.5481	13895	-0.8121	14135	-2.1362	14375	-1.5671
13660	-1.3996	13900	-0.8139	14140	-2.1430	14380	-1.5894
13665	-1.3048	13905	-0.8489	14145	-2.1193	14385	-1.5803
13670	-1.2475	13910	-0.8585	14150	-2.0681	14390	-1.5540
13675	-1.2003	13915	-0.8914	14155	-2.0372	14395	-1.5264

C' VALUE FOR H_2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
14400	-1.4872	14640	-4.0518	14880	-8.2860	15120	-3.5076
14405	-1.4934	14645	-4.0297	14885	-7.2151	15125	-3.4241
14410	-1.5390	14650	-4.0636	14890	-7.3121	15130	-3.3014
14415	-1.6005	14655	-4.1378	14895	-6.7320	15135	-3.1565
14420	-1.6782	14660	-4.1849	14900	-6.6154	15140	-3.0579
14425	-1.7528	14665	-4.1956	14905	-6.2962	15145	-2.9789
14430	-1.8533	14670	-4.1931	14910	-6.0271	15150	-2.9530
14435	-1.9809	14675	-4.2088	14915	-5.8367	15155	-2.9890
14440	-2.1349	14680	-4.3019	14920	-5.6451	15160	-2.9876
14445	-2.3590	14685	-4.4145	14925	-5.5293	15165	-2.9416
14450	-2.5890	14690	-4.5336	14930	-5.4937	15170	-2.8570
14455	-2.8218	14695	-4.6296	14935	-5.5236	15175	-2.7266
14460	-3.0549	14700	-4.7032	14940	-5.4386	15180	-2.6485
14465	-3.1783	14705	-4.7988	14945	-5.2572	15185	-2.6412
14470	-3.2700	14710	-4.9771	14950	-5.0886	15190	-2.6301
14475	-3.3418	14715	-5.2093	14955	-4.9568	15195	-2.6226
14480	-3.4918	14720	-5.4659	14960	-4.9341	15200	-2.5743
14485	-3.7140	14725	-5.7205	14965	-4.9975	15205	-2.4779
14490	-3.9236	14730	-5.8938	14970	-4.9005	15210	-2.4374
14495	-4.0763	14735	-5.9757	14975	-4.7778	15215	-2.4126
14500	-4.0468	14740	-6.1228	14980	-4.6105	15220	-2.4090
14505	-3.8950	14745	-6.3138	14985	-4.4267	15225	-2.4162
14510	-3.8151	14750	-6.5047	14990	-4.3241	15230	-2.3643
14515	-3.8794	14755	-6.6957	14995	-4.1922	15235	-2.3288
14520	-3.9883	14760	-6.8866	15000	-4.1032	15240	-2.2784
14525	-4.1436	14765	-7.0776	15005	-4.0698	15245	-2.2373
14530	-4.3060	14770	-7.2685	15010	-4.0564	15250	-2.2223
14535	-4.3293	14775	-7.4595	15015	-4.1142	15255	-2.1926
14540	-4.3949	14780	-7.6504	15020	-4.1251	15260	-2.1908
14545	-4.3828	14785	-7.8414	15025	-4.0964	15265	-2.1699
14550	-4.2459	14790	-8.0323	15030	-4.0356	15270	-2.1787
14555	-4.0702	14795	-8.2233	15035	-3.8750	15275	-2.2266
14560	-3.8880	14800	-8.4142	15040	-3.7780	15280	-2.2849
14565	-3.8147	14805	-8.6052	15045	-3.7034	15285	-2.3693
14570	-3.7961	14810	-8.7961	15050	-3.6681	15290	-2.3966
14575	-3.8097	14815	-8.9871	15055	-3.7193	15295	-2.3833
14580	-3.8575	14820	-9.1780	15060	-3.7592	15300	-2.3803
14585	-3.8560	14825	-9.3689	15065	-3.7759	15305	-2.4113
14590	-3.8818	14830	-9.5599	15070	-3.7260	15310	-2.4648
14595	-3.8974	14835	-9.7509	15075	-3.6716	15315	-2.5176
14600	-3.8521	14840	-9.9418	15080	-3.6394	15320	-2.4713
14605	-3.8157	14845	-10.3316	15085	-3.6363	15325	-2.3637
14610	-3.7836	14850	-10.7209	15090	-3.7066	15330	-2.1887
14615	-3.7971	14855	-11.1105	15095	-3.7636	15335	-2.0256
14620	-3.8945	14860	-11.5000	15100	-3.8181	15340	-1.9446
14625	-4.0326	14865	-11.4987	15105	-3.7928	15345	-1.9722
14630	-4.1214	14870	-10.4278	15110	-3.7108	15350	-2.0928
14635	-4.0940	14875	-9.3569	15115	-3.6242	15355	-2.2590

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
15360	-2.3989	15600	-3.7291	15840	-3.1947	16370	-10.3971
15365	-2.5171	15605	-3.7732	15845	-3.3998	16375	-10.1940
15370	-2.5361	15610	-3.8016	15850	-3.5939	16380	-9.9909
15375	-2.4923	15615	-3.8328	15855	-3.7096	16385	-9.7878
15380	-2.4177	15620	-3.8766	15860	-3.6964	16390	-9.5847
15385	-2.2713	15625	-3.9027	15865	-3.5455	16395	-9.3816
15390	-2.1349	15630	-3.8584	15870	-3.2841	16400	-9.1786
15395	-2.0347	15635	-3.7926	15875	-3.0479	16405	-8.9755
15400	-1.9625	15640	-3.7301	15880	-2.9037	16410	-8.7724
15405	-1.9222	15645	-3.6545	15885	-2.8080	16415	-8.5693
15410	-1.8976	15650	-3.6340	15890	-2.7595	16420	-8.3662
15415	-1.8729	15655	-3.6267	15895	-2.7540	16425	-8.1632
15420	-1.8536	15660	-3.6339	15900	-2.7410	16430	-7.9601
15425	-1.8413	15665	-3.6752	15905	-2.7670	16435	-7.7570
15430	-1.8331	15670	-3.6983	15910	-2.8532	16440	-7.5539
15435	-1.8414	15675	-3.6336	15915	-2.9589	16445	-7.3508
15440	-1.8648	15680	-3.5028	15920	-3.1259	16450	-7.1494
15445	-1.9214	15685	-3.3554	15925	-3.2298	16455	-6.8180
15450	-1.9908	15690	-3.2589	15930	-3.2180	16460	-6.5302
15455	-2.0536	15695	-3.2685	15935	-3.1654	16465	-6.4543
15460	-2.1152	15700	-3.3195	15940	-3.0998	16470	-6.2863
15465	-2.1657	15705	-3.3702	15945	-3.1091	16475	-6.1938
15470	-2.2331	15710	-3.3635	15950	-3.1760	16480	-5.9299
15475	-2.3124	15715	-3.2840	15955	-3.3378	16485	-5.6915
15480	-2.4290	15720	-3.2428	15960	-3.5663	16490	-5.5198
15485	-2.5760	15725	-3.2209	15965	-3.8598	16495	-5.3782
15490	-2.7079	15730	-3.2296	15970	-4.3120	16500	-5.3306
15495	-2.8624	15735	-3.2096	15975	-4.7891	16505	-5.3272
15500	-2.9450	15740	-3.1454	15980	-5.4739	16510	-5.2921
15505	-2.9724	15745	-3.1022	15985	-6.6385	16515	-5.2649
15510	-3.0229	15750	-3.0435	15990	-7.1646	16520	-5.1700
15515	-3.0727	15755	-3.0620	15995	-7.1831	16525	-4.9871
15520	-3.1800	15760	-3.1078	16000	-7.2015	16530	-4.8256
15525	-3.2782	15765	-3.1722	16005	-7.6789	16535	-4.6473
15530	-3.3245	15770	-3.2437	16010	-8.1563	16540	-4.5012
15535	-3.3020	15775	-3.2598	16015	-8.6337	16545	-4.4097
15540	-3.2575	15780	-3.2653	16020	-9.1110	16550	-4.3642
15545	-3.2617	15785	-3.2445	16025	-9.5884	16555	-4.3866
15550	-3.3008	15790	-3.2066	16030	-10.0658	16560	-4.3796
15555	-3.3894	15795	-3.1768	16035	-10.5432	16565	-4.3202
15560	-3.4953	15800	-3.1040	16040	-11.0206	16570	-4.1628
15565	-3.6454	15805	-2.9940	16045	-11.4980	16575	-3.9797
15570	-3.7816	15810	-2.8571	16340	-11.5000	16580	-3.8505
15575	-3.8712	15815	-2.7624	16345	-11.4125	16585	-3.7752
15580	-3.9231	15820	-2.7229	16350	-11.2094	16590	-3.7734
15585	-3.8201	15825	-2.7428	16355	-11.0063	16595	-3.7790
15590	-3.7773	15830	-2.8473	16360	-10.8032	16600	-3.7421
15595	-3.7557	15835	-3.0083	16365	-10.6001	16605	-3.5869

C' VALUE FOR H2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
16610	-3.4319	16850	-2.1535	17090	-3.4614	17330	-3.1324
16615	-3.3139	16855	-2.1496	17095	-3.5044	17335	-3.1573
16620	-3.2366	16860	-2.1247	17100	-3.5299	17340	-3.1683
16625	-3.2492	16865	-2.0934	17105	-3.5671	17345	-3.1012
16630	-3.2553	16870	-2.0452	17110	-3.5872	17350	-3.0393
16635	-3.2157	16875	-1.9288	17115	-3.6023	17355	-2.9982
16640	-3.1457	16880	-1.8641	17120	-3.6128	17360	-2.9382
16645	-3.0382	16885	-1.8167	17125	-3.6375	17365	-2.9067
16650	-2.9328	16890	-1.7871	17130	-3.6652	17370	-2.8859
16655	-2.8650	16895	-1.8406	17135	-3.6693	17375	-2.8928
16660	-2.8171	16900	-1.8713	17140	-3.6805	17380	-2.9370
16665	-2.7648	16905	-1.8991	17145	-3.7041	17385	-2.9384
16670	-2.7038	16910	-1.9382	17150	-3.7406	17390	-2.8955
16675	-2.6191	16915	-1.9489	17155	-3.7928	17395	-2.8042
16680	-2.5253	16920	-1.9700	17160	-3.8926	17400	-2.7350
16685	-2.4558	16925	-1.9817	17165	-3.9455	17405	-2.7382
16690	-2.4194	16930	-1.9454	17170	-3.9704	17410	-2.7618
16695	-2.4273	16935	-1.8680	17175	-4.0274	17415	-2.8307
16700	-2.4535	16940	-1.7761	17180	-4.0047	17420	-2.8677
16705	-2.4835	16945	-1.7178	17185	-4.0230	17425	-2.8744
16710	-2.4693	16950	-1.7020	17190	-4.0500	17430	-2.9168
16715	-2.3987	16955	-1.7234	17195	-4.0411	17435	-2.9015
16720	-2.3405	16960	-1.7460	17200	-4.0877	17440	-2.8804
16725	-2.2767	16965	-1.7333	17205	-4.0696	17445	-2.8460
16730	-2.2560	16970	-1.7178	17210	-4.0102	17450	-2.7933
16735	-2.2480	16975	-1.7226	17215	-3.9533	17455	-2.7900
16740	-2.1899	16980	-1.7481	17220	-3.8587	17460	-2.7844
16745	-2.1422	16985	-1.8160	17225	-3.8176	17465	-2.7386
16750	-2.1155	16990	-1.9163	17230	-3.7969	17470	-2.6726
16755	-2.1503	16995	-2.0151	17235	-3.7735	17475	-2.6238
16760	-2.2432	17000	-2.1207	17240	-3.7503	17480	-2.6204
16765	-2.2885	17005	-2.2379	17245	-3.7458	17485	-2.6922
16770	-2.2678	17010	-2.3387	17250	-3.7737	17490	-2.8118
16775	-2.1986	17015	-2.4333	17255	-3.7964	17495	-2.9318
16780	-2.1390	17020	-2.5587	17260	-3.8398	17500	-3.0400
16785	-2.1304	17025	-2.6642	17265	-3.8484	17505	-3.1086
16790	-2.1259	17030	-2.7601	17270	-3.7913	17510	-3.1766
16795	-2.0807	17035	-2.8876	17275	-3.6943	17515	-3.1939
16800	-1.9659	17040	-2.9658	17280	-3.6055	17520	-3.1433
16805	-1.8532	17045	-3.0382	17285	-3.5359	17525	-2.9930
16810	-1.7543	17050	-3.1464	17290	-3.5310	17530	-2.7925
16815	-1.7036	17055	-3.2188	17295	-3.5351	17535	-2.6357
16820	-1.7391	17060	-3.3008	17300	-3.5028	17540	-2.5308
16825	-1.7958	17065	-3.4338	17305	-3.3825	17545	-2.4897
16830	-1.9187	17070	-3.5032	17310	-3.2586	17550	-2.5063
16835	-2.0420	17075	-3.5154	17315	-3.1416	17555	-2.5127
16840	-2.1133	17080	-3.5297	17320	-3.0686	17560	-2.4907
16845	-2.1677	17085	-3.4718	17325	-3.0889	17565	-2.4713

C' VALUE FOR H_2O

WAVE #	C'	WAVE #	C'	WAVE #	C'	WAVE #	C'
17570	-2.4414	17645	-4.1353	17720	-4.6453	17795	-4.7458
17575	-2.4524	17650	-4.2313	17725	-4.6761	17800	-4.9024
17580	-2.5034	17655	-4.3517	17730	-4.7557	17805	-5.1362
17585	-2.5649	17660	-4.4721	17735	-4.8850	17810	-5.5333
17590	-2.6616	17665	-4.6368	17740	-5.0655	17815	-6.2253
17595	-2.7854	17670	-4.7221	17745	-5.2044	17820	-6.8532
17600	-2.9377	17675	-4.7259	17750	-5.1841	17825	-7.3187
17605	-3.1122	17680	-4.6961	17755	-5.0356	17830	-7.9138
17610	-3.2798	17685	-4.6329	17760	-4.8843	17835	-8.5089
17615	-3.4184	17690	-4.5754	17765	-4.8221	17840	-9.1040
17620	-3.5391	17695	-4.5205	17770	-4.8165	17845	-9.6991
17625	-3.6975	17700	-4.5280	17775	-4.8373	17850	-10.2942
17630	-3.8446	17705	-4.5682	17780	-4.8186	17855	-10.8893
17635	-3.9992	17710	-4.5978	17785	-4.7781	17860	-11.4844
17640	-4.1215	17715	-4.6235	17790	-4.7470		

APPENDIX B

Spectral Plots of the Parameter C' for NH_3, CO_2, CO, CH_4, NO, NO_2 N_2O, O_2, O_3, SO_2, and H_2O from the Tables in Appendix A.

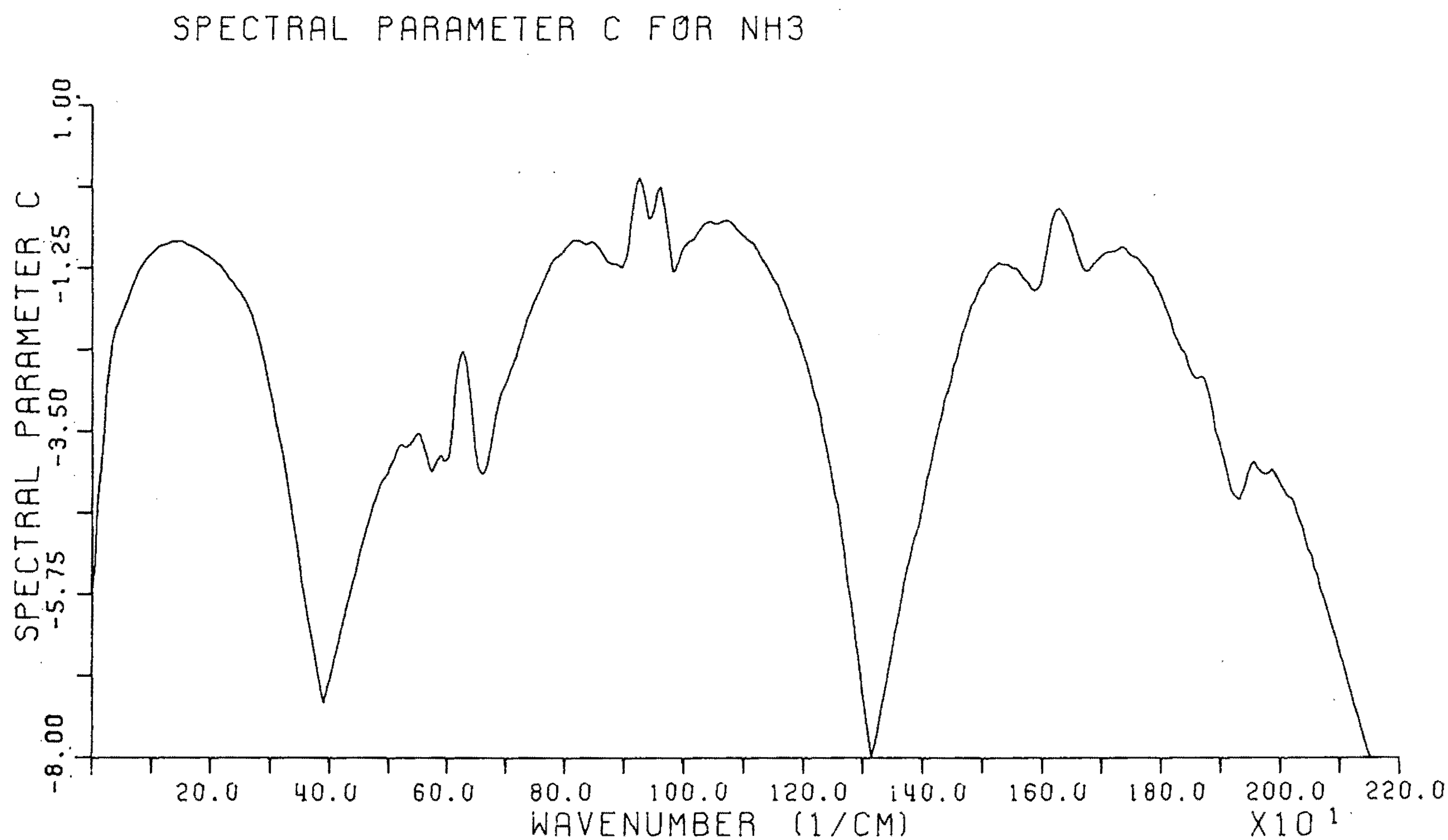

SPECTRAL PARAMETER C FØR NH3
SPECTRAL PARAMETER C
1.00
-1.25
-3.50
-5.75
-8.00
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
WAVENUMBER (1/CM)
X10 1

Figure B1

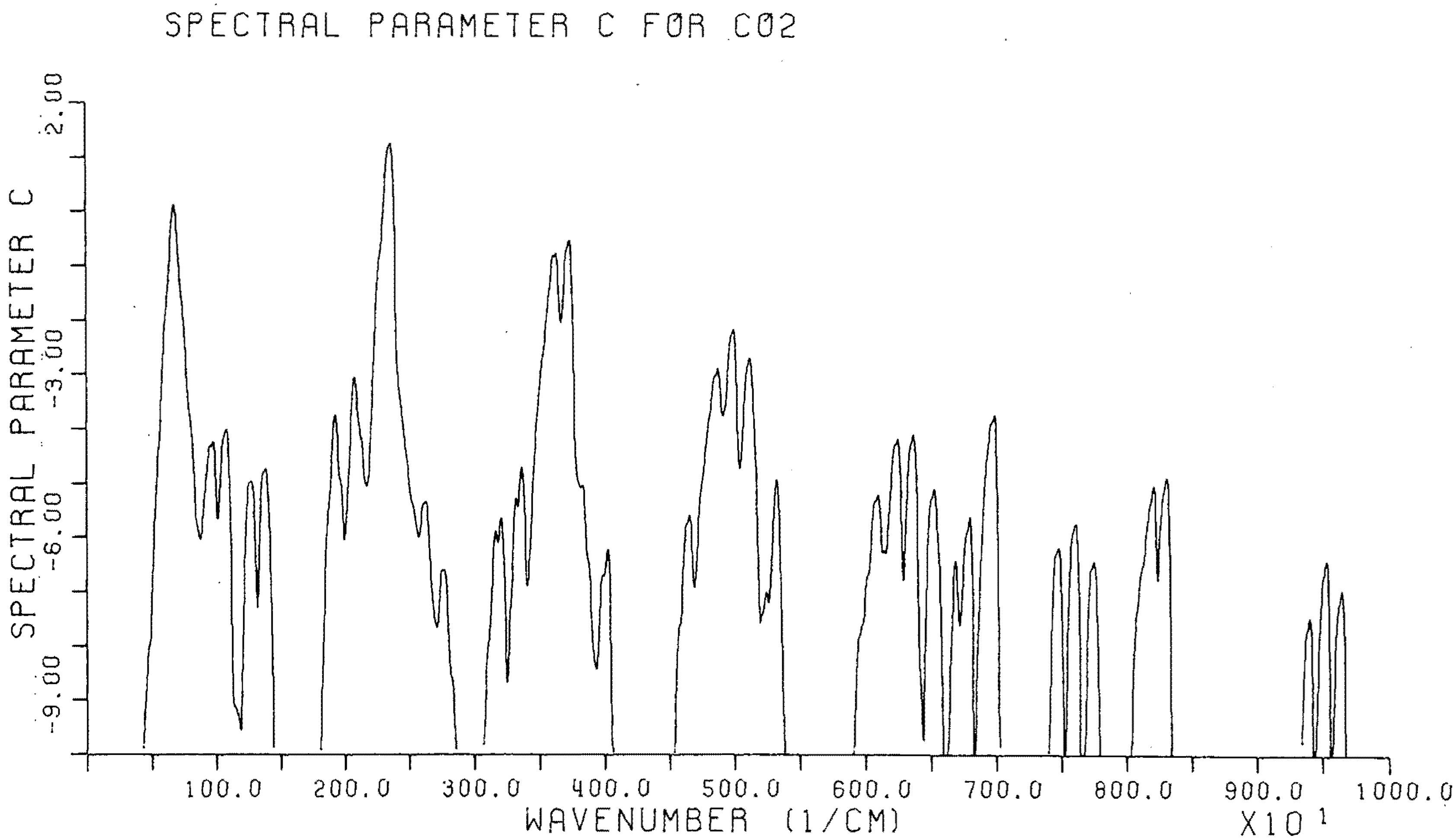

SPECTRAL PARAMETER C FØR CØ2
SPECTRAL PARAMETER C
2.00
-3.00
-6.00
-9.00
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
WAVENUMBER (1/CM)
X10 1

Figure B2

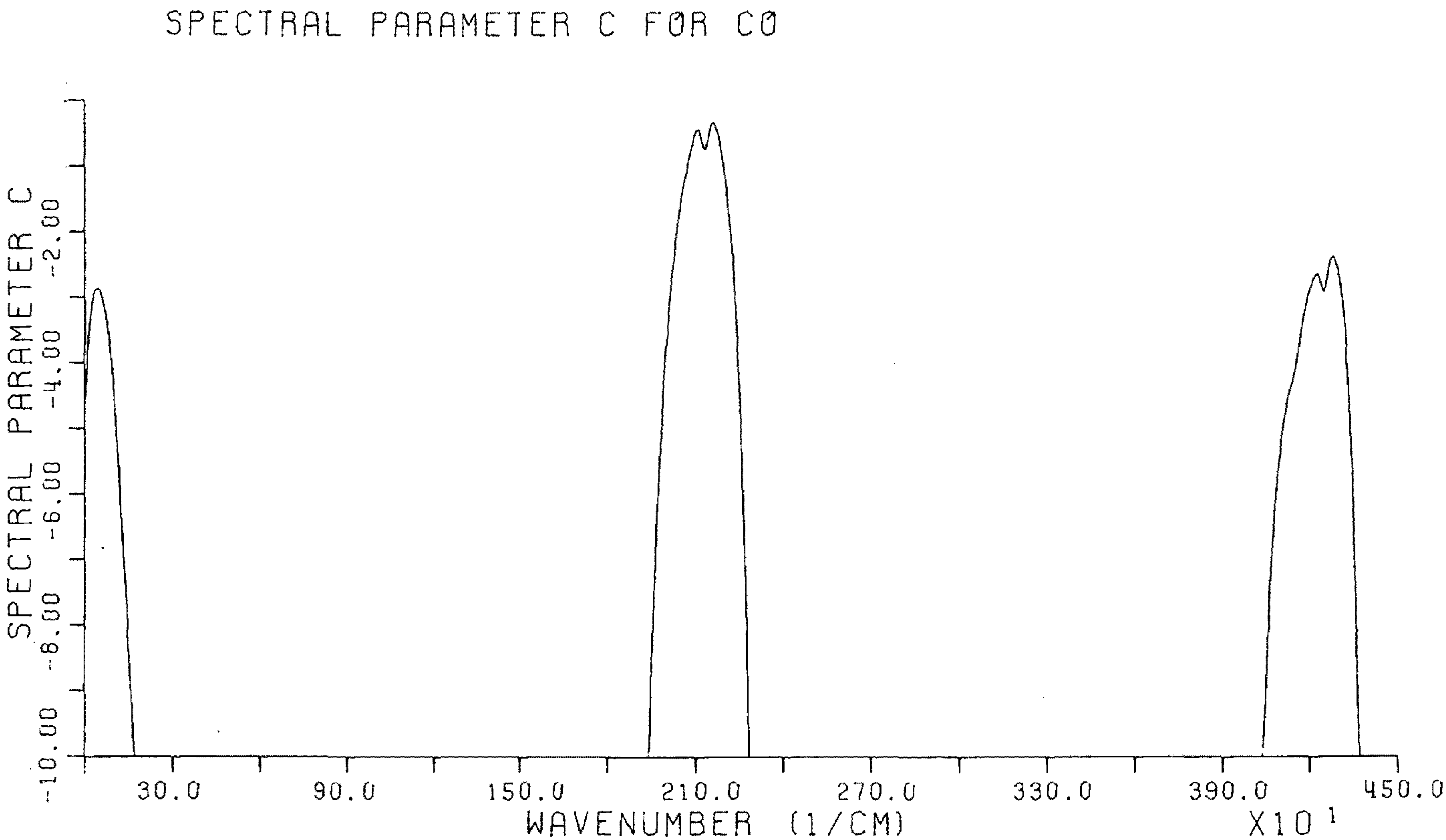

SPECTRAL PARAMETER C FOR CO
SPECTRAL PARAMETER C
-2.00
-4.00
-6.00
-8.00
-10.00
30.0
90.0
150.0
210.0
270.0
330.0
390.0
450.0
WAVENUMBER (1/CM)
X10 1

Figure B3

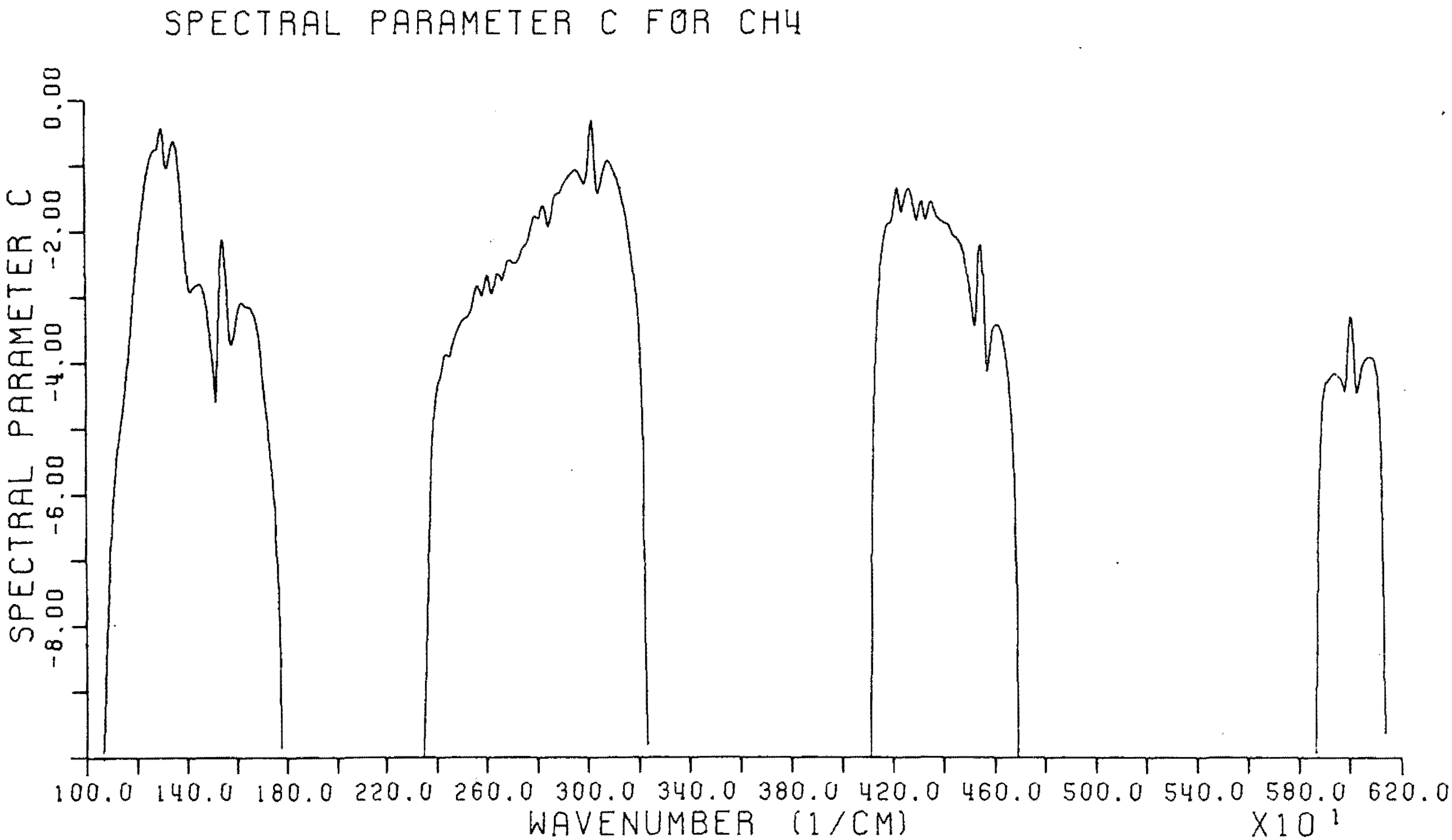

SPECTRAL PARAMETER C FØR CH4
SPECTRAL PARAMETER C
0.00
-2.00
-4.00
-6.00
-8.00
100.0 140.0 180.0 220.0 260.0 300.0 340.0 380.0 420.0 460.0 500.0 540.0 580.0 620.0
WAVENUMBER (1/CM)
X10 1

Figure B4

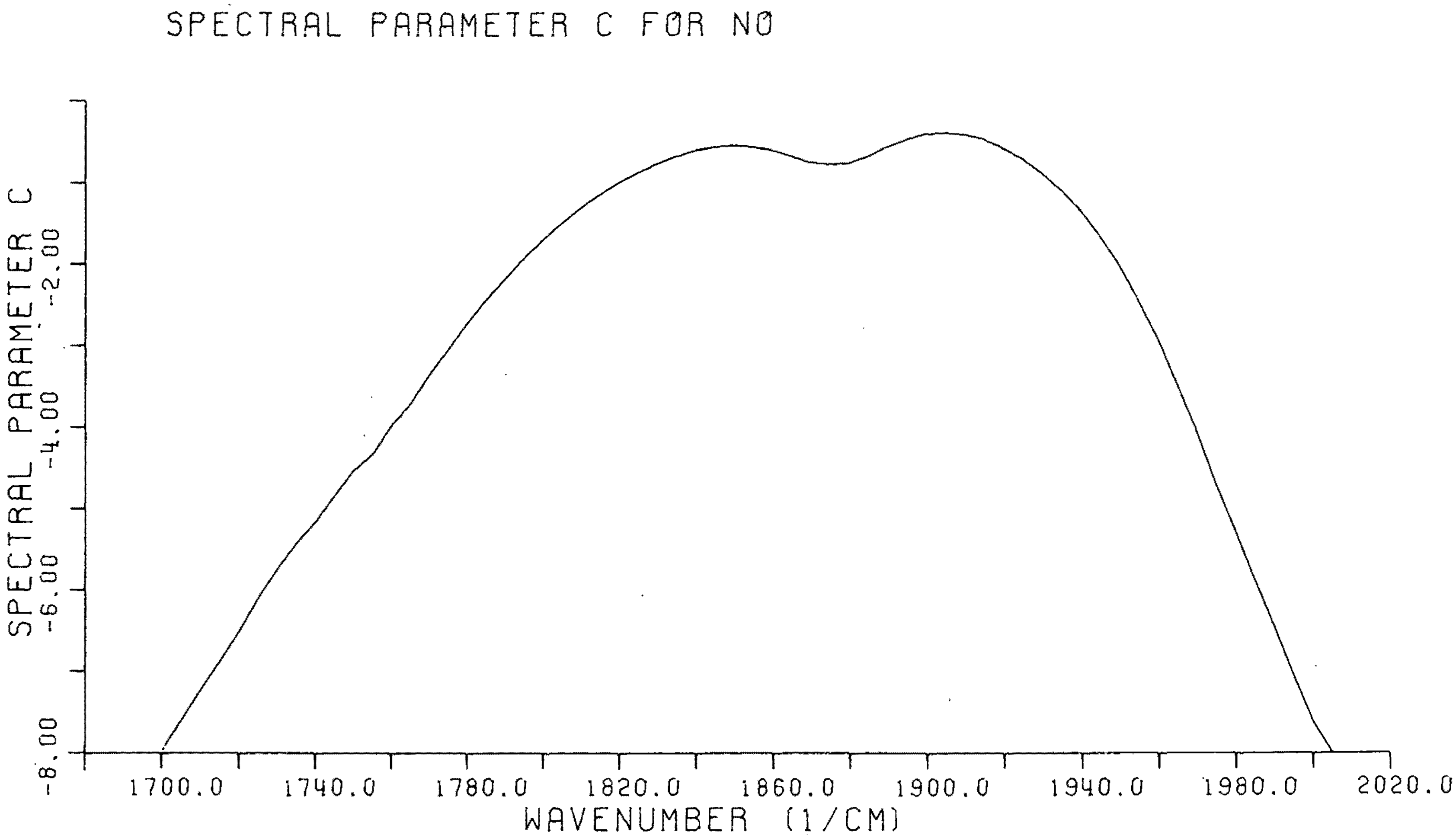

SPECTRAL PARAMETER C FOR NO
SPECTRAL PARAMETER C
-2.00
-4.00
-6.00
-8.00
1700.0
1740.0
1780.0
1820.0
1860.0
1900.0
1940.0
1980.0
2020.0
WAVENUMBER (1/CM)

Figure B5

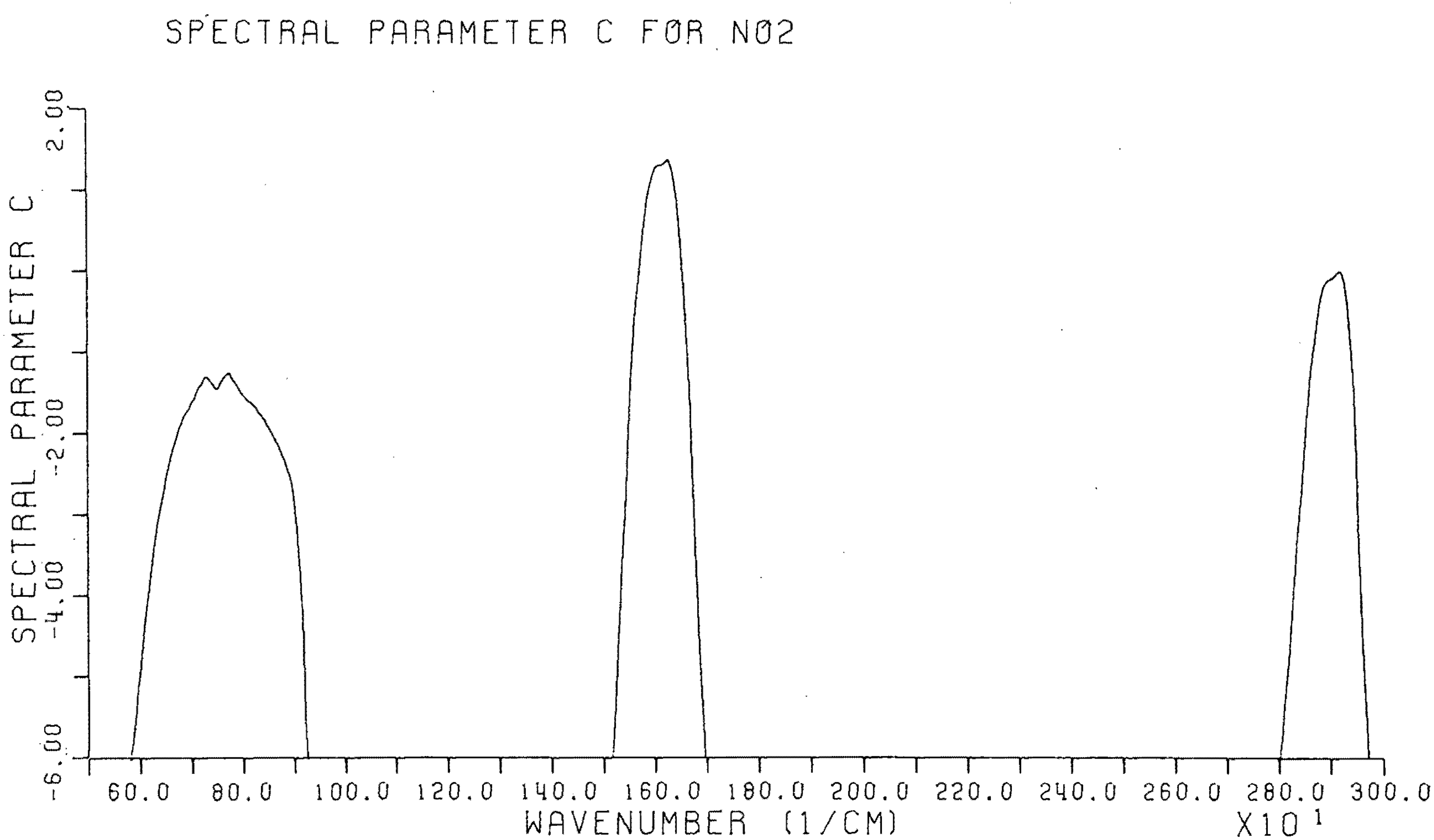

SPECTRAL PARAMETER C FØR NØ2
SPECTRAL PARAMETER C
2.00
-2.00
-4.00
-6.00
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
260.0
280.0
300.0
WAVENUMBER (1/CM)
X10 1

Figure B6

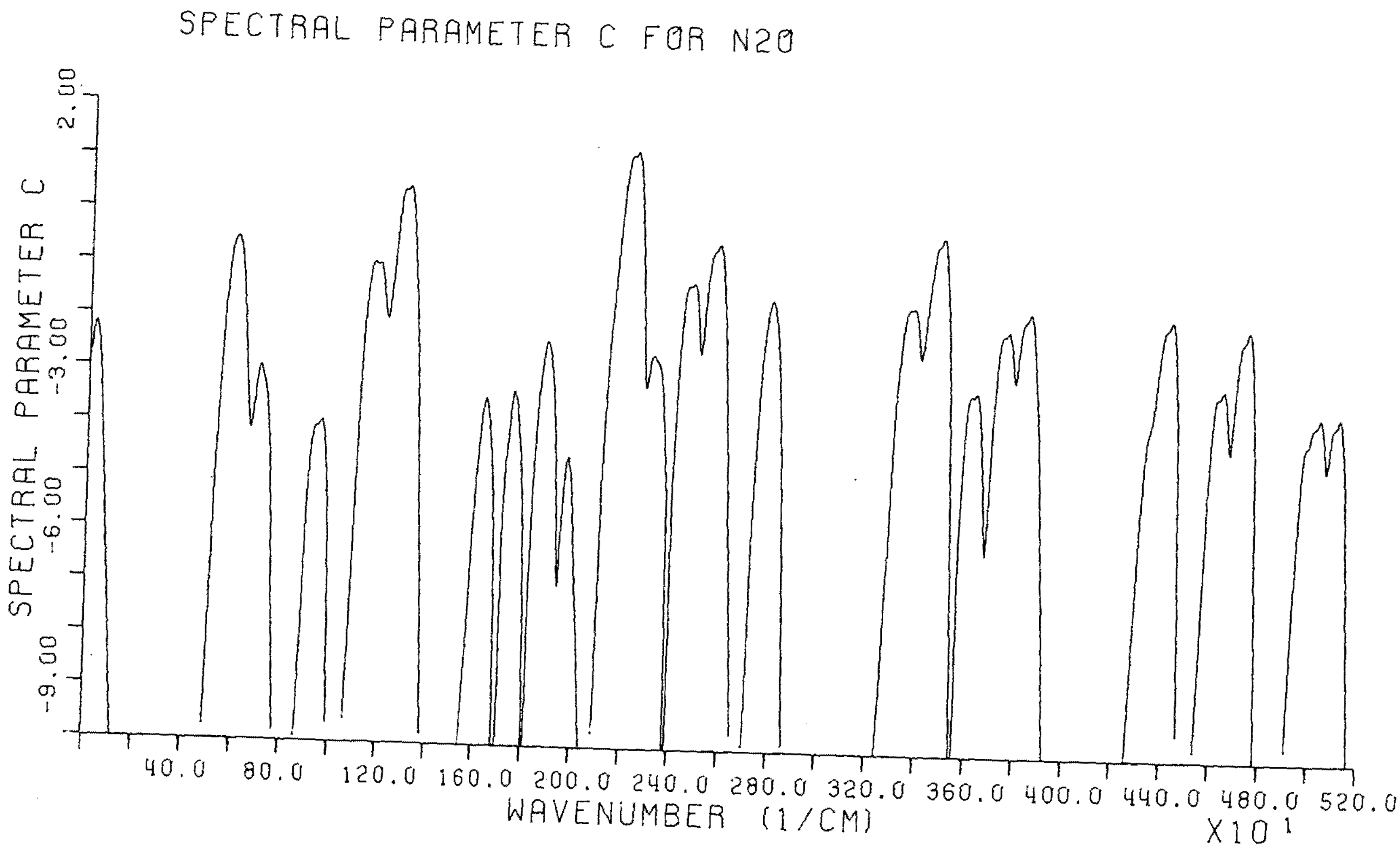

SPECTRAL PARAMETER C FØR N2Ø
SPECTRAL PARAMETER C
2.00
-3.00
-6.00
-9.00
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
440.0
480.0
520.0
WAVENUMBER (1/CM)
X10 1

Figure B7

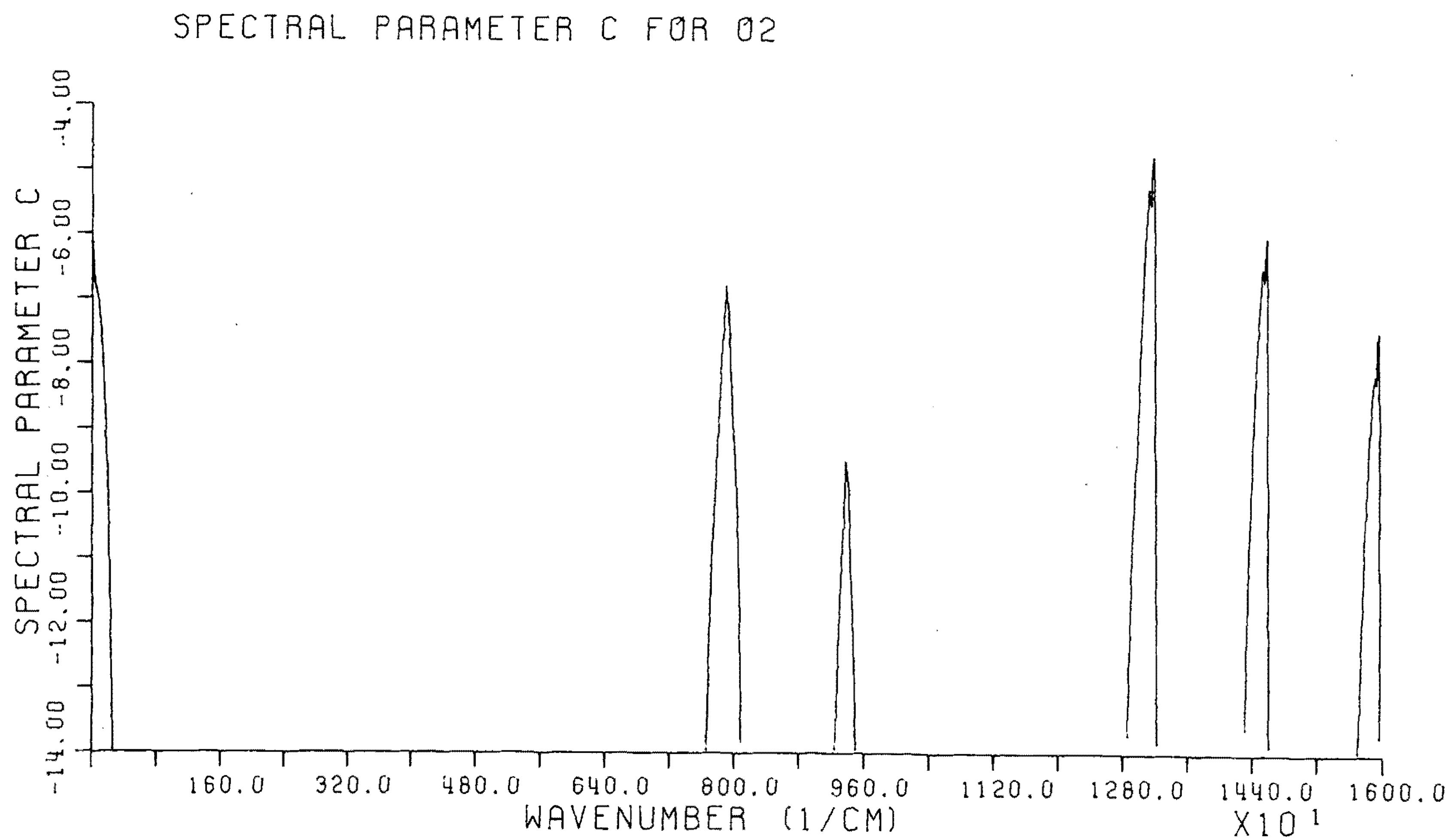

SPECTRAL PARAMETER C FØR 02
SPECTRAL PARAMETER C
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
160.0
320.0
480.0
640.0
800.0
960.0
1120.0
1280.0
1440.0
1600.0
WAVENUMBER (1/CM)
X10 1

Figure B8

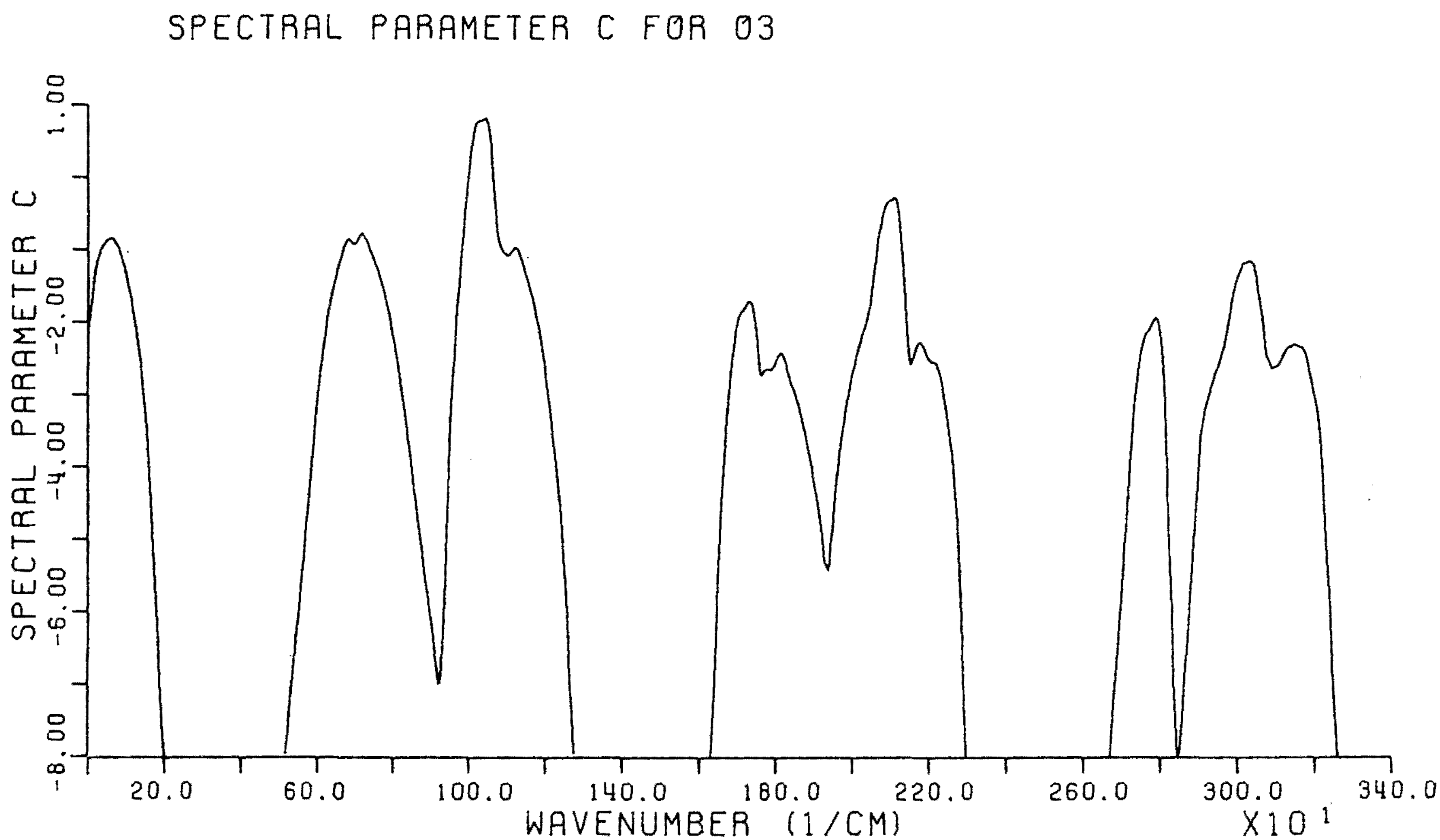

SPECTRAL PARAMETER C FOR O3
SPECTRAL PARAMETER C
1.00
-2.00
-4.00
-6.00
-8.00
20.0
60.0
100.0
140.0
180.0
220.0
260.0
300.0
340.0
WAVENUMBER (1/CM)
X10 1

Figure B9

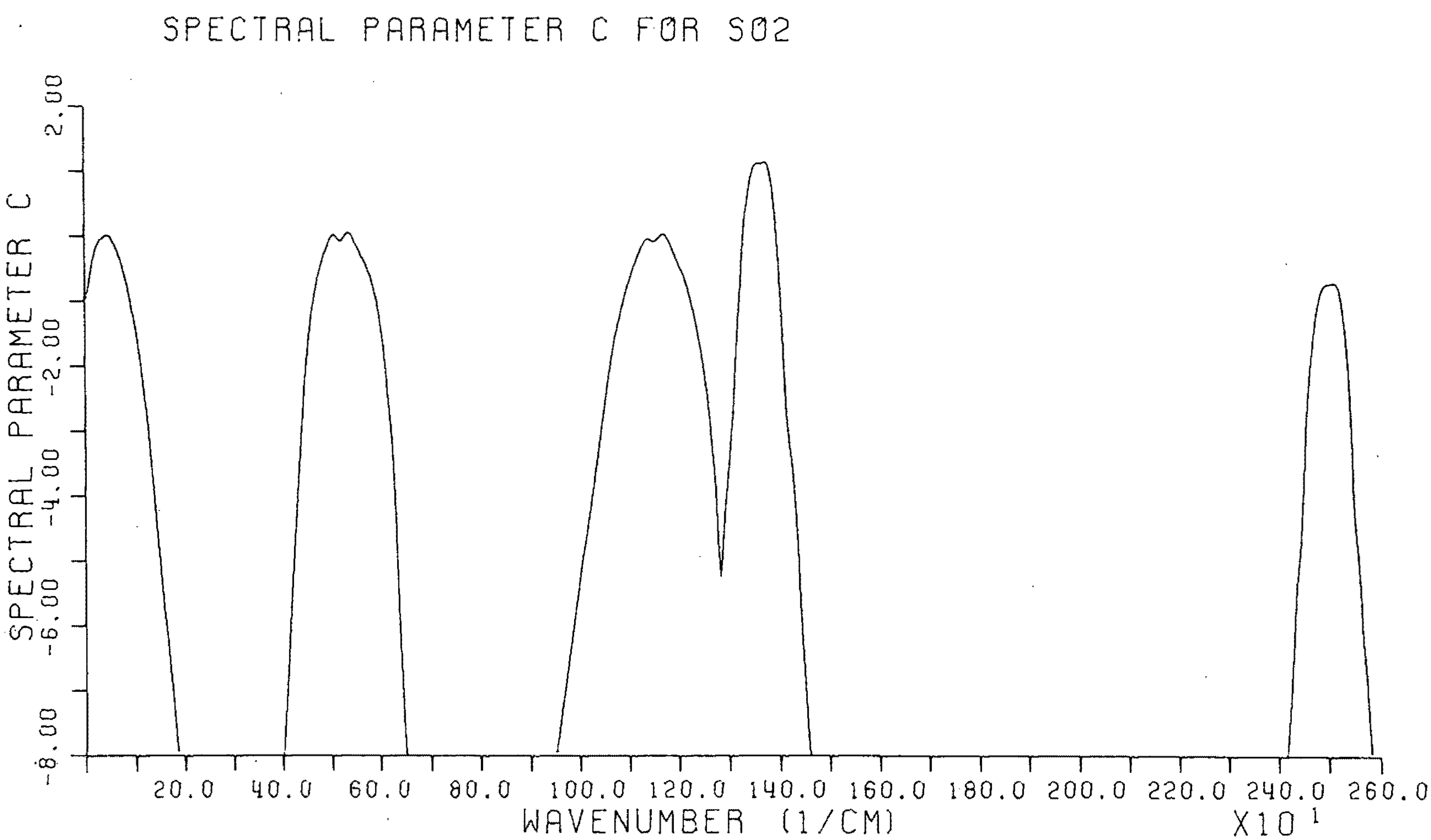

SPECTRAL PARAMETER C FØR SØ2
SPECTRAL PARAMETER C
2.00
-2.00
-4.00
-6.00
-8.00
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
260.0
WAVENUMBER (1/CM)
X10 1

Figure B10

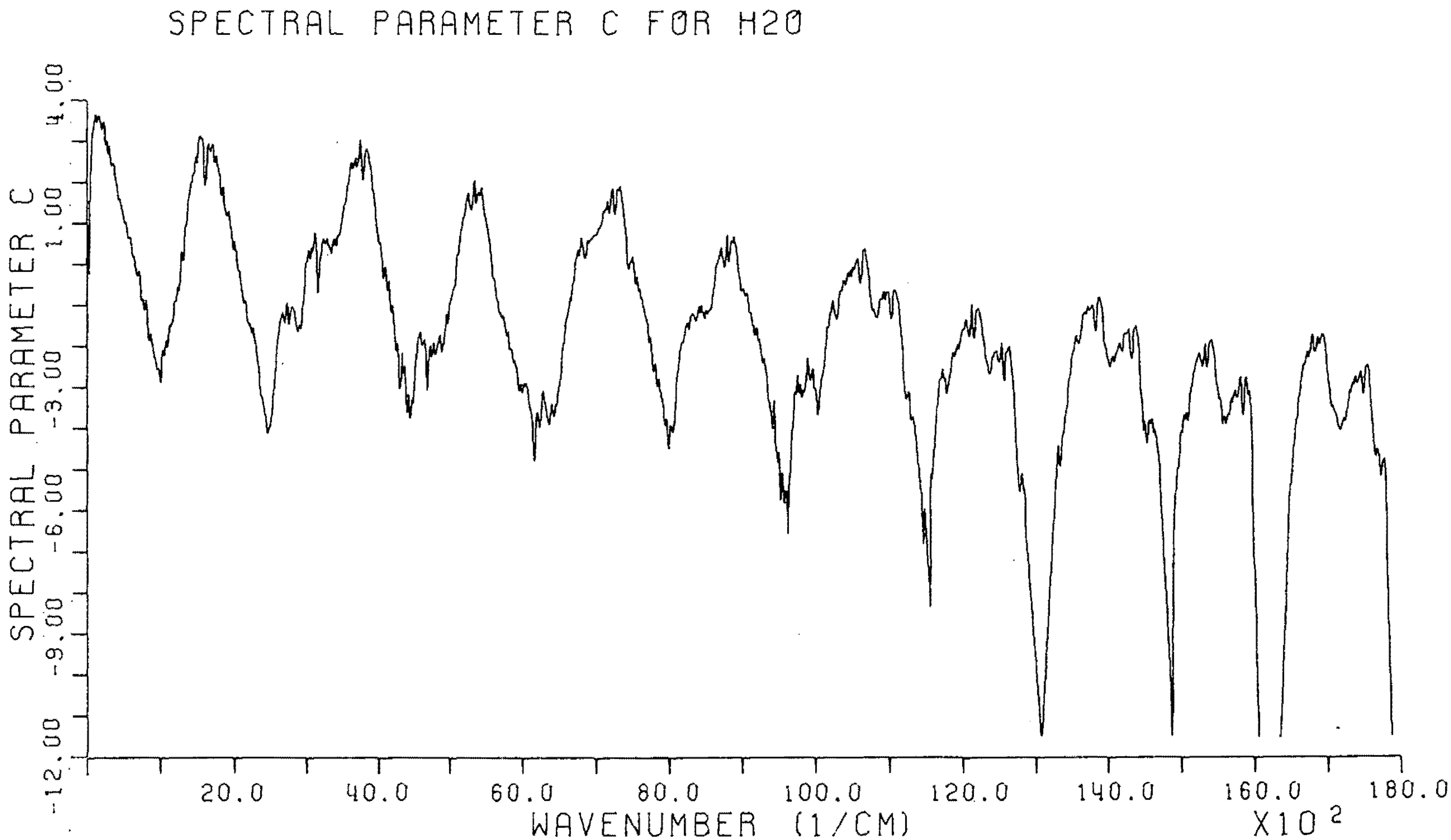

SPECTRAL PARAMETER C FOR H2O
SPECTRAL PARAMETER C
4.00
1.00
-3.00
-6.00
-9.00
-12.00
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
WAVENUMBER (1/CM)
X10 2

Figure B11

APPENDIX C

Transmission Functions (τ versus CW) for NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, and SO_2.

Transmission Functions for O_3 and H_2O appear on pages 16 and 17, respectively.

The top transmittance curve, in the region where log (cw) is negative, corresponds to the largest value of A, while the lower curves correspond to values of A is descending order.

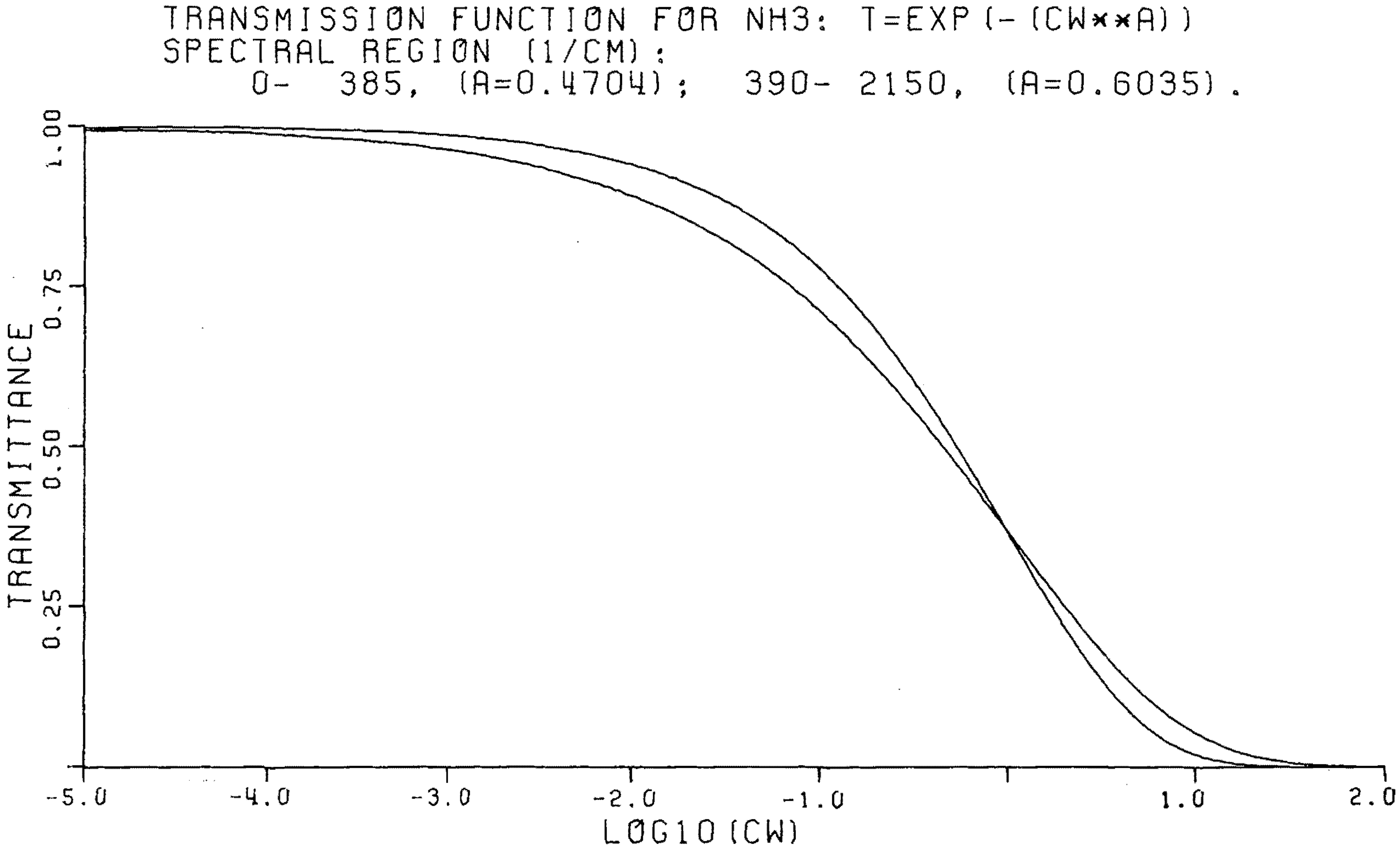

TRANSMISSION FUNCTION FOR NH3: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
0- 385, (A=0.4704); 390- 2150, (A=0.6035).
TRANSMITTANCE
1.00
0.75
0.50
0.25
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C1

TRANSMISSION FUNCTION FOR CO2: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
425- 835, (A=0.6176); 840- 1440, (A=0.6810);
1805- 2855, (A=0.6033); 3070- 3755, (A=0.6146);
3760- 4065, (A=0.6513); 4530- 5380, (A=0.6050);
5905- 7025, (A=0.6160); 7395- 7785, 8030- 8335,
9340- 9670, (A=0.7070).

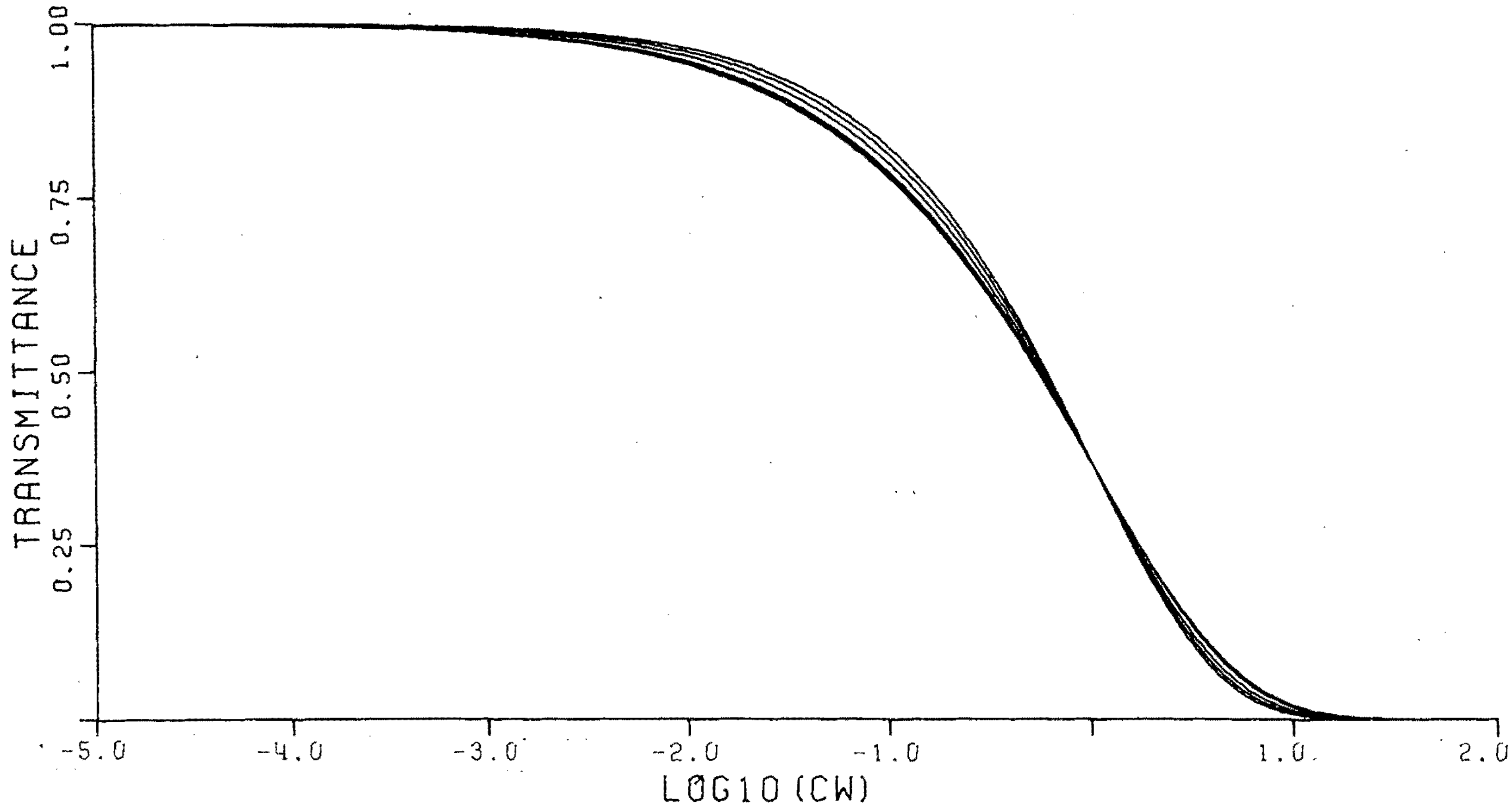


Figure C2

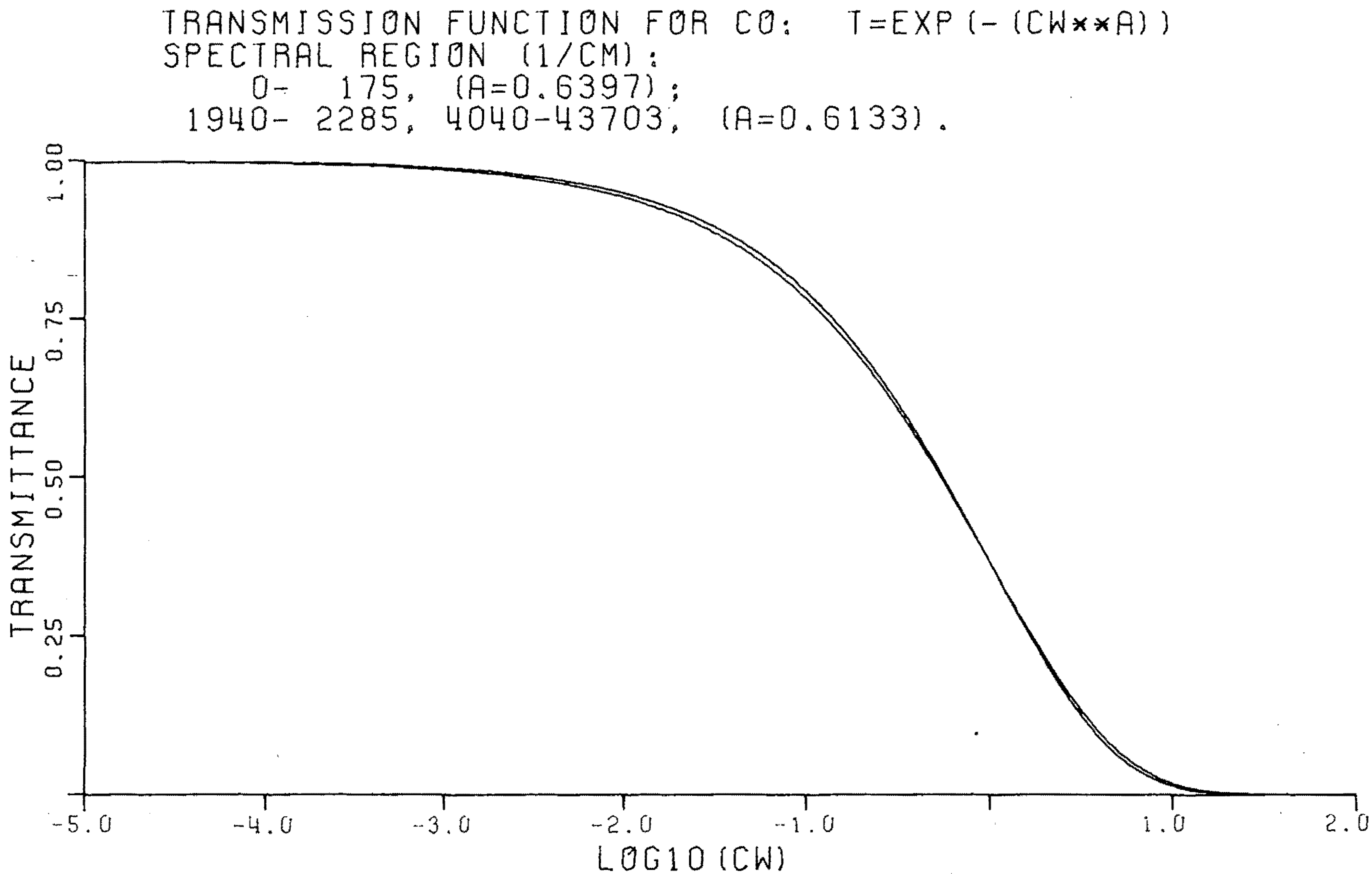

TRANSMISSION FUNCTION FOR CO: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
0- 175, (A=0.6397);
1940- 2285, 4040-43703, (A=0.6133).
TRANSMITTANCE
0.25
0.50
0.75
1.00
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C3

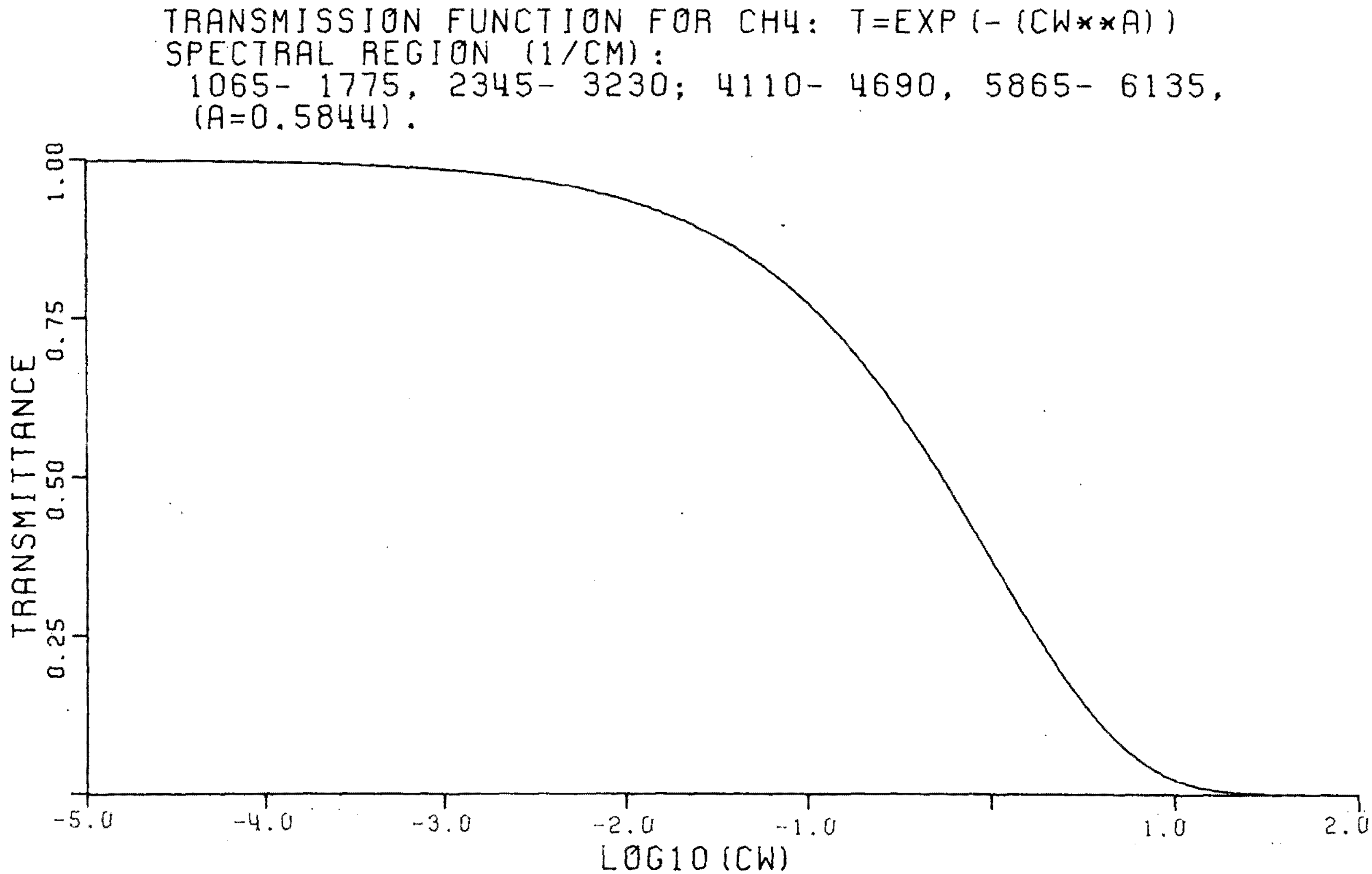

TRANSMISSION FUNCTION FOR CH4: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
1065- 1775, 2345- 3230; 4110- 4690, 5865- 6135,
(A=0.5844).
TRANSMITTANCE
1.00
0.75
0.50
0.25
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C4

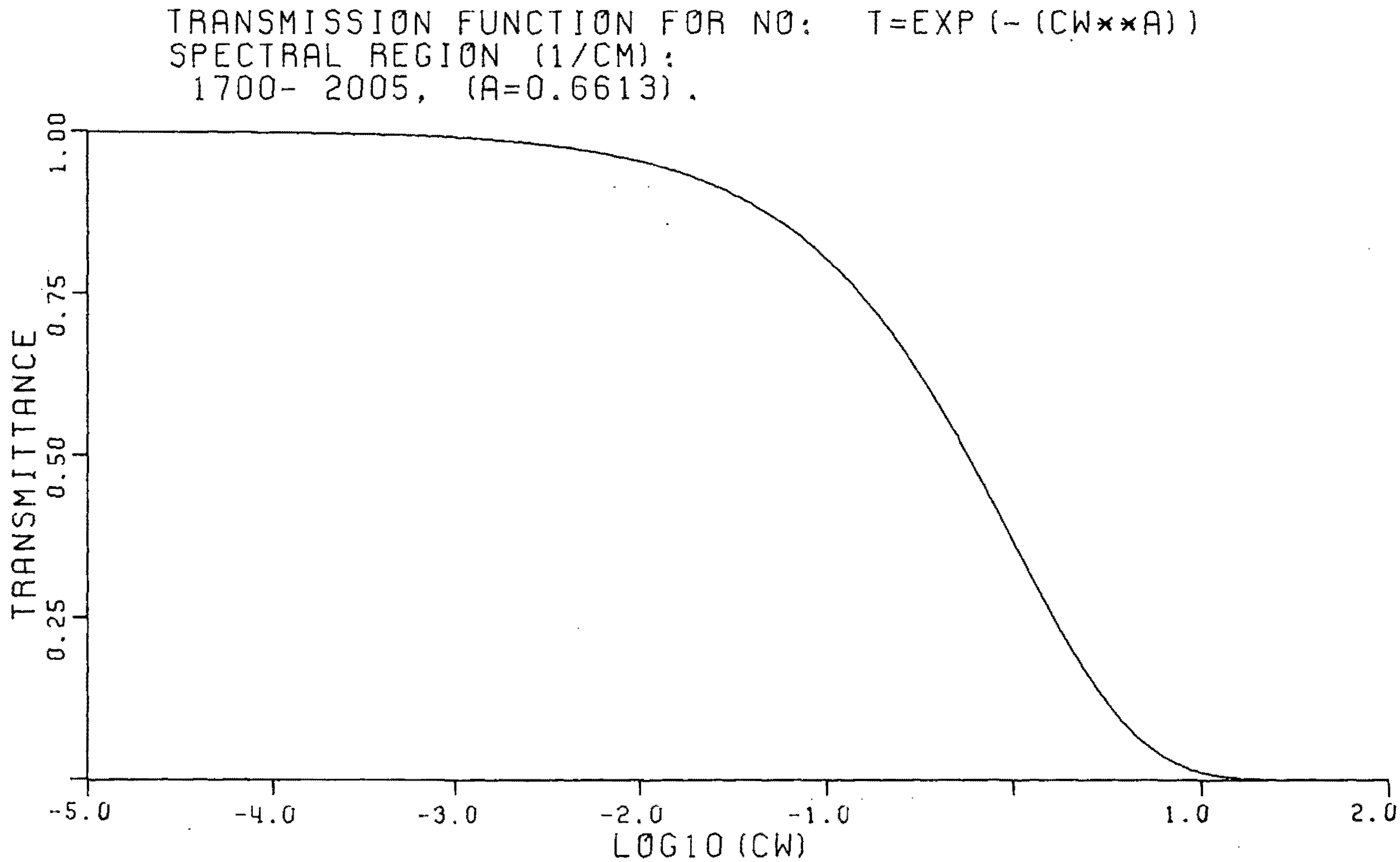
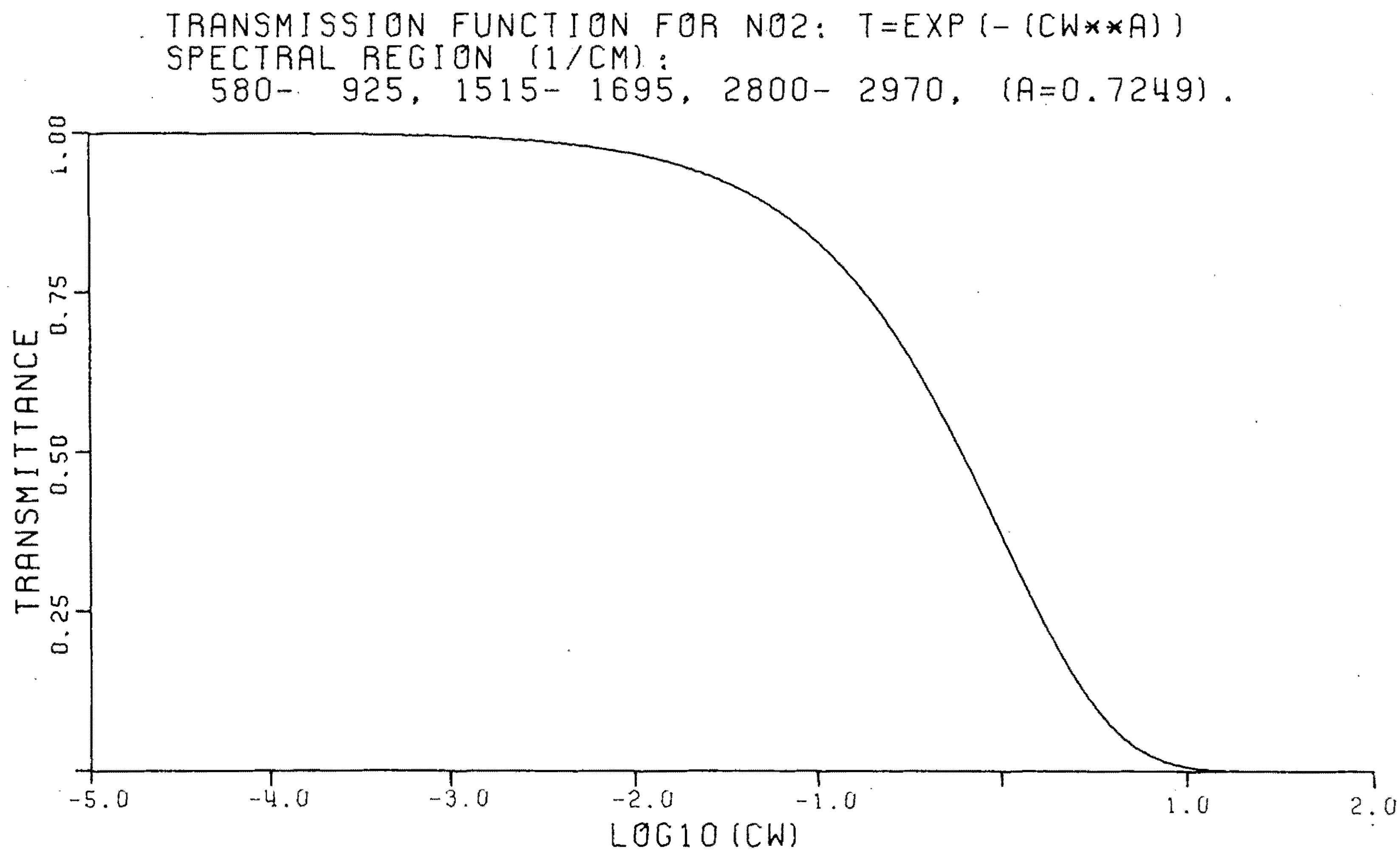

TRANSMISSION FUNCTION FOR NO: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
1700- 2005, (A=0.6613).
TRANSMITTANCE
0.25
0.50
0.75
1.00
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C5



TRANSMISSION FUNCTION FOR NO2: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
580- 925, 1515- 1695, 2800- 2970, (A=0.7249).
TRANSMITTANCE
1.00
0.75
0.50
0.25
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C6

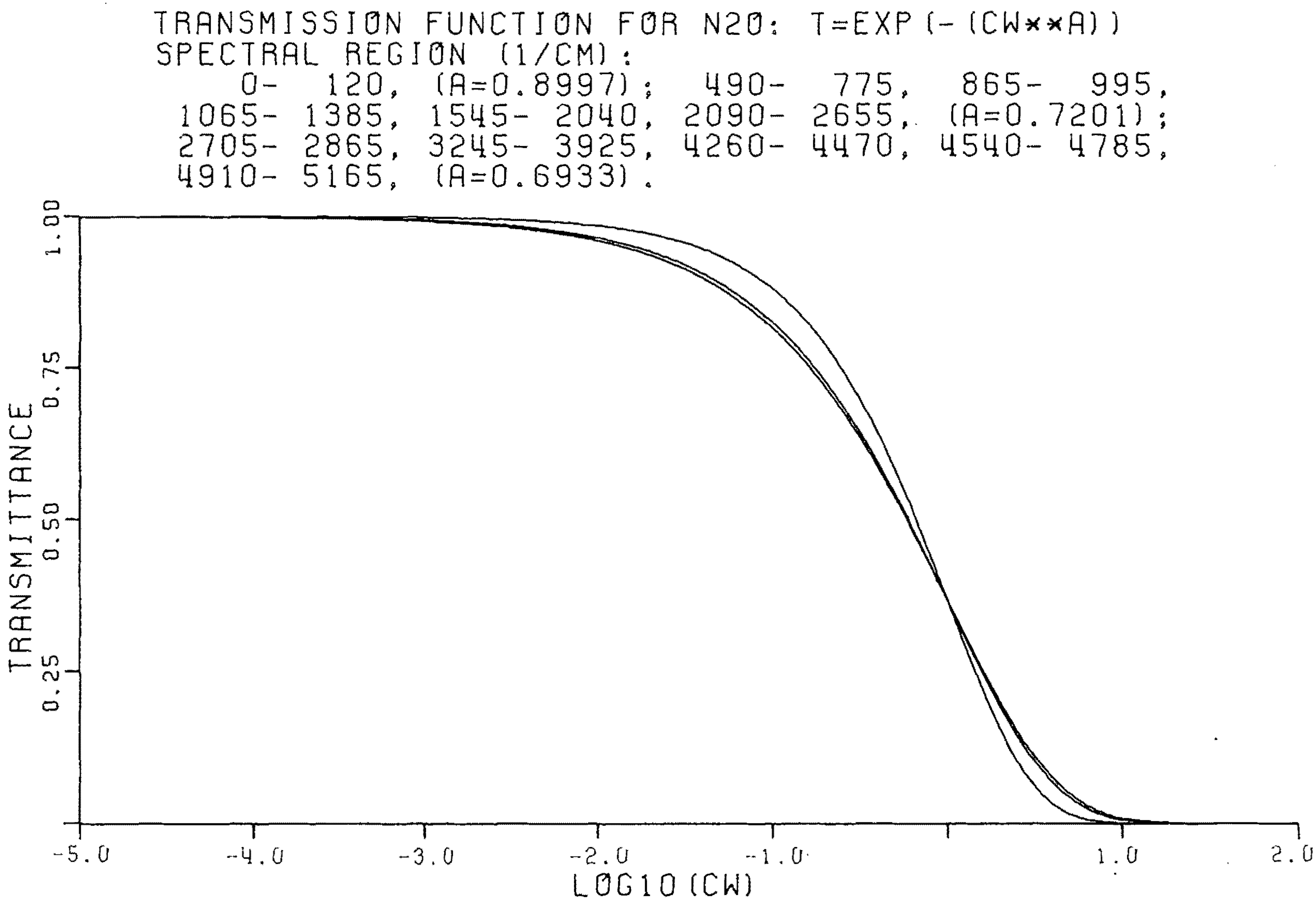

TRANSMISSION FUNCTION FOR N2O: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
0- 120, (A=0.8997); 490- 775, 865- 995,
1065- 1385, 1545- 2040, 2090- 2655, (A=0.7201);
2705- 2865, 3245- 3925, 4260- 4470, 4540- 4785,
4910- 5165, (A=0.6933).
TRANSMITTANCE
1.00
0.75
0.50
0.25
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C7

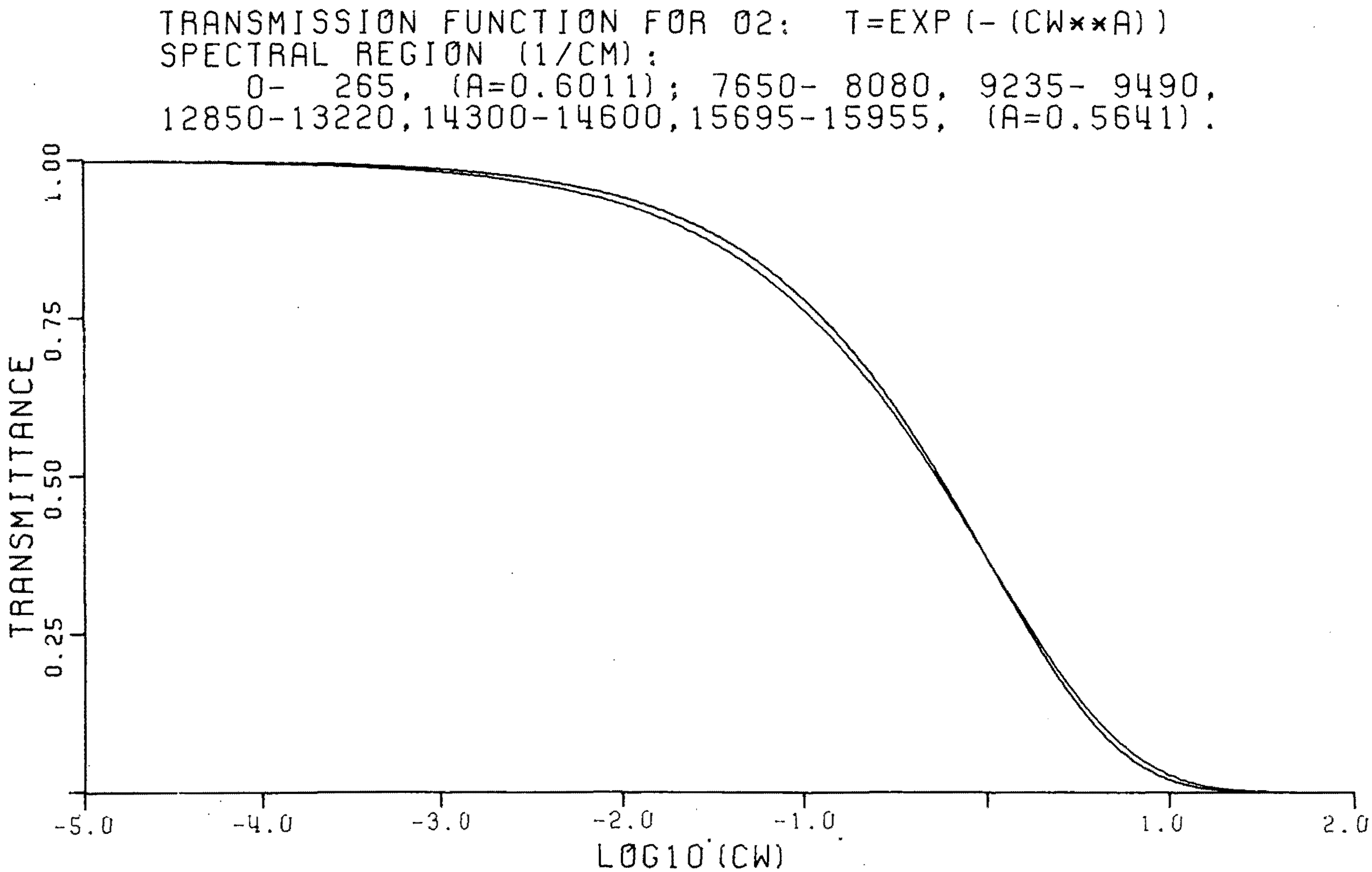

TRANSMISSION FUNCTION FOR O2: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
0- 265, (A=0.6011); 7650- 8080, 9235- 9490,
12850-13220,14300-14600,15695-15955, (A=0.5641).
TRANSMITTANCE
1.00
0.75
0.50
0.25
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C8

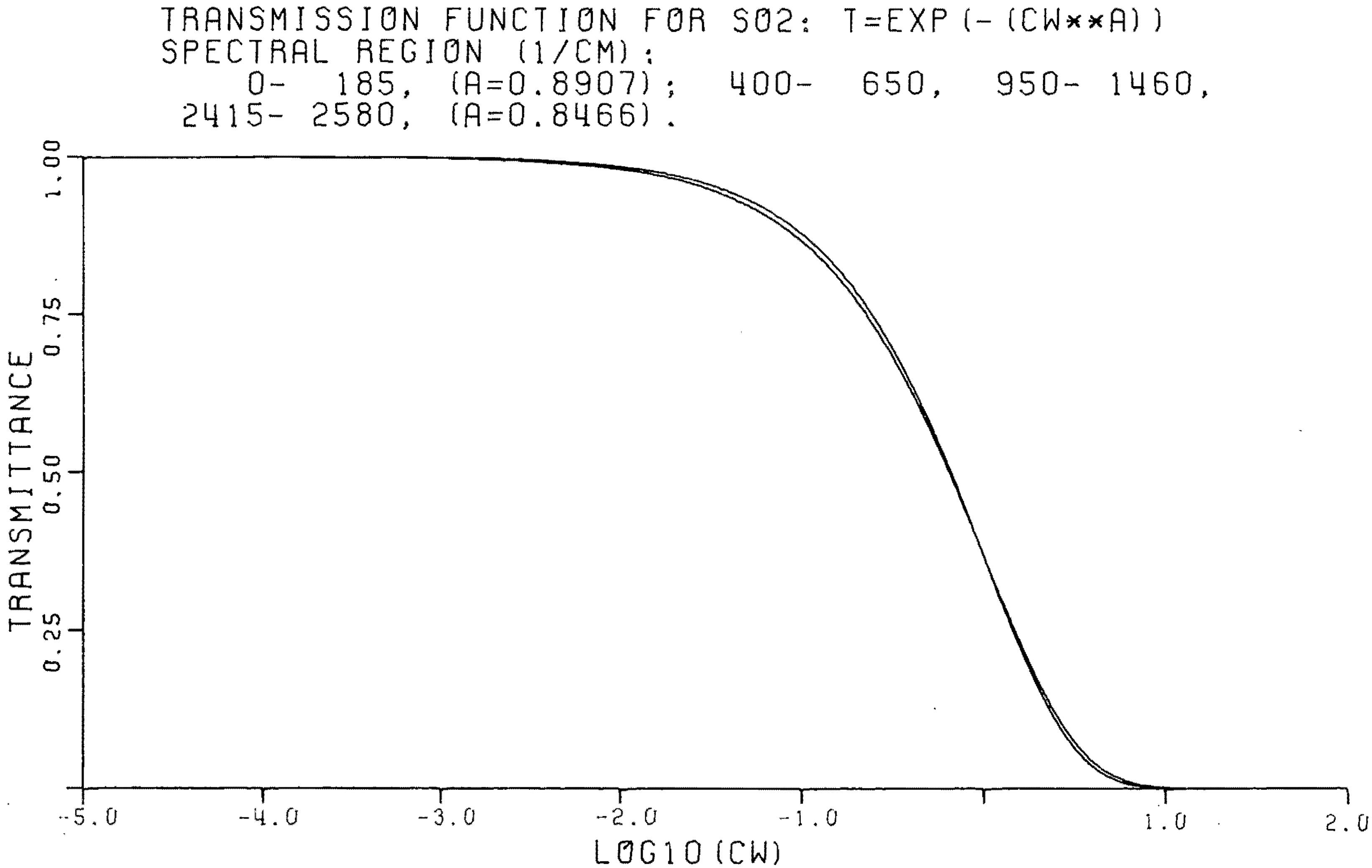
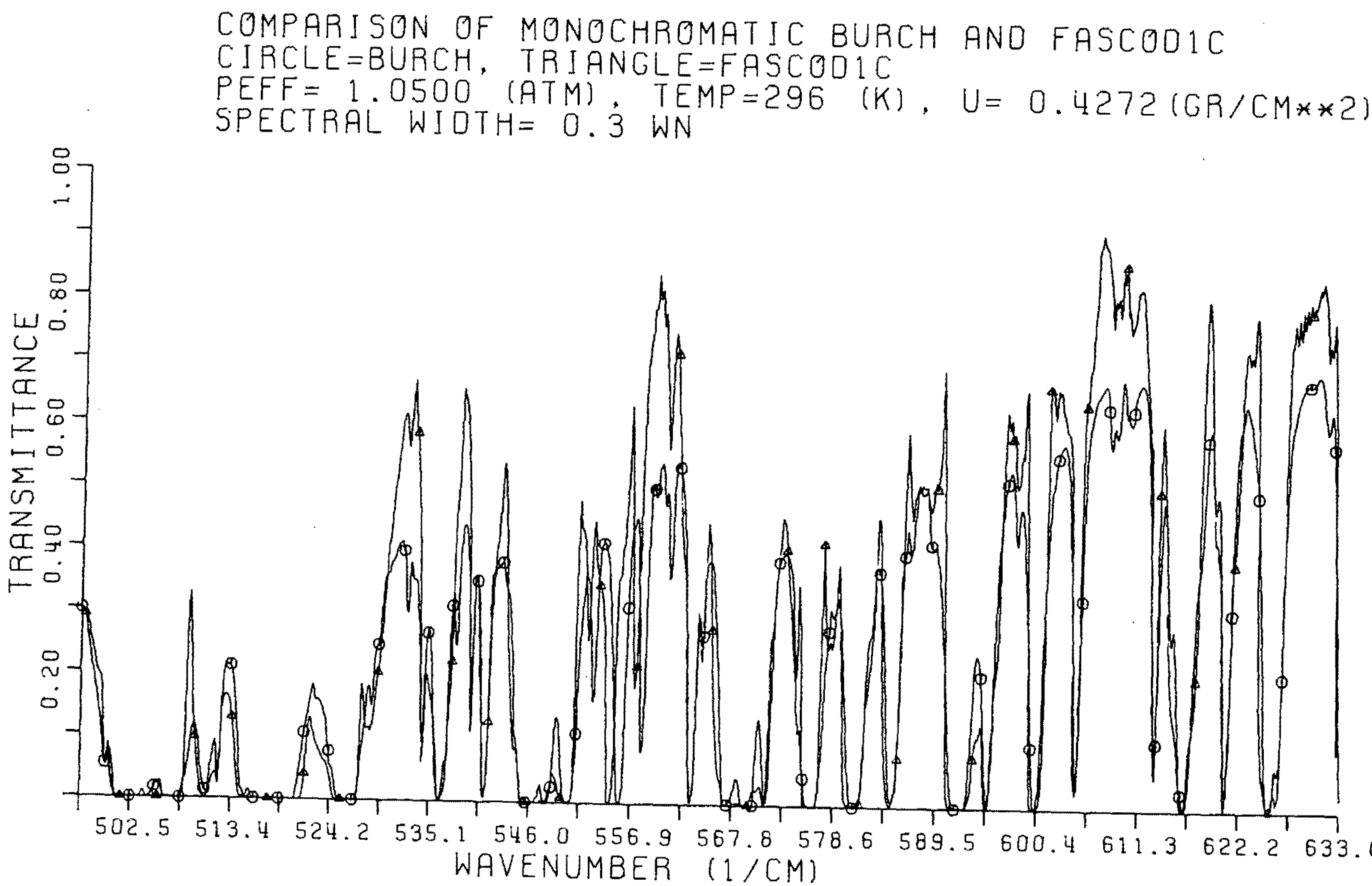

TRANSMISSION FUNCTION FOR SO2: T=EXP(-(CW**A))
SPECTRAL REGION (1/CM):
0- 185, (A=0.8907); 400- 650, 950- 1460,
2415- 2580, (A=0.8466).
TRANSMITTANCE
0.25
0.50
0.75
1.00
-5.0
-4.0
-3.0
-2.0
-1.0
1.0
2.0
LOG10(CW)

Figure C9

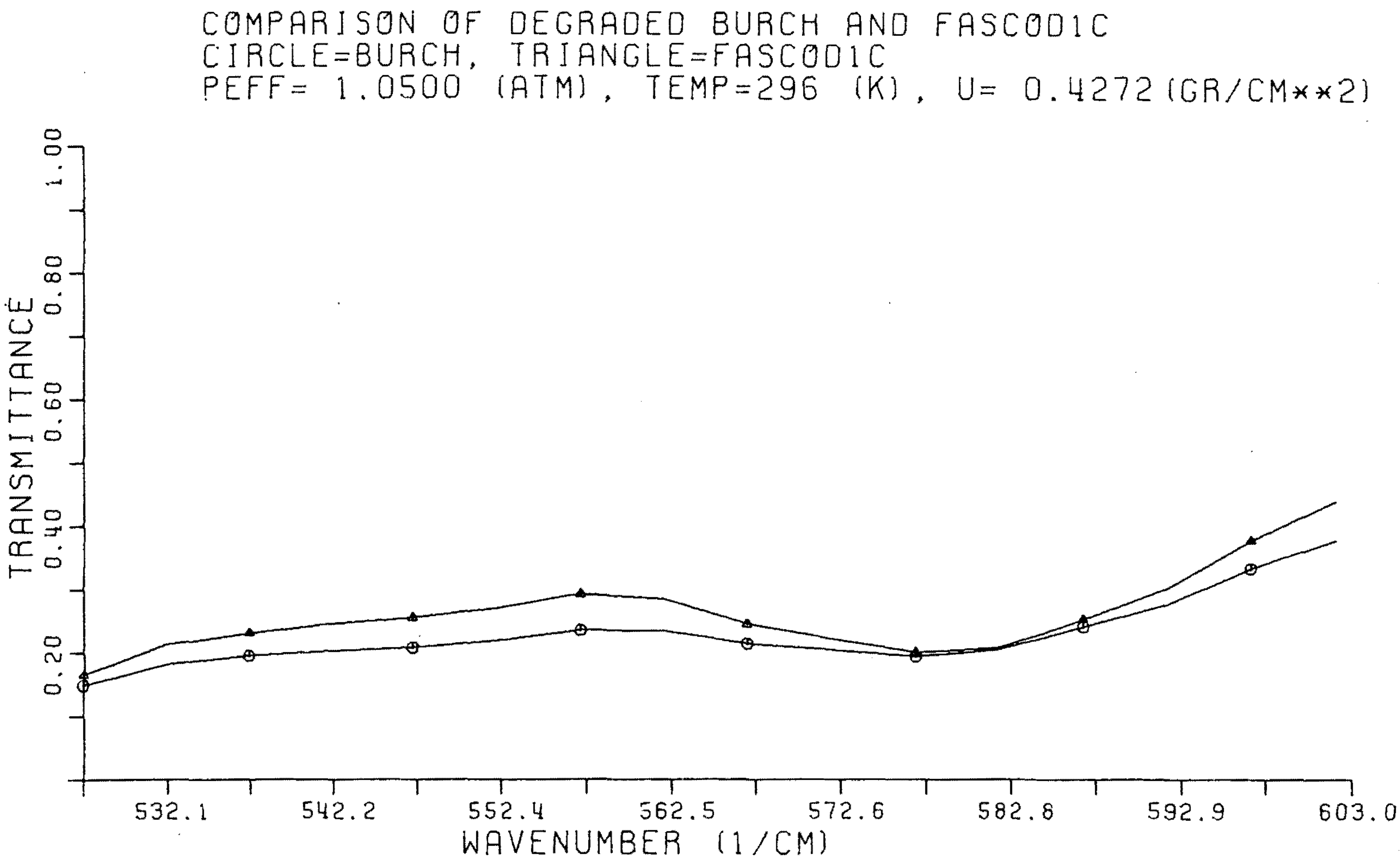
APPENDIX D

Comparisons Between High Resolution and Degraded Line-By-Line Calculations with Measurements of H_2O.



COMPARISON OF MONOCHROMATIC BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 1.0500 (ATM), TEMP=296 (K), U= 0.4272(GR/CM**2)
SPECTRAL WIDTH= 0.3 WN
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
502.5
513.4
524.2
535.1
546.0
556.9
567.8
578.6
589.5
600.4
611.3
622.2
633.0
WAVENUMBER (1/CM)

Figure D1a



COMPARISON OF DEGRADED BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 1.0500 (ATM), TEMP=296 (K), U= 0.4272 (GR/CM**2)
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
532.1
542.2
552.4
562.5
572.6
582.8
592.9
603.0
WAVENUMBER (1/CM)

Figure D1b

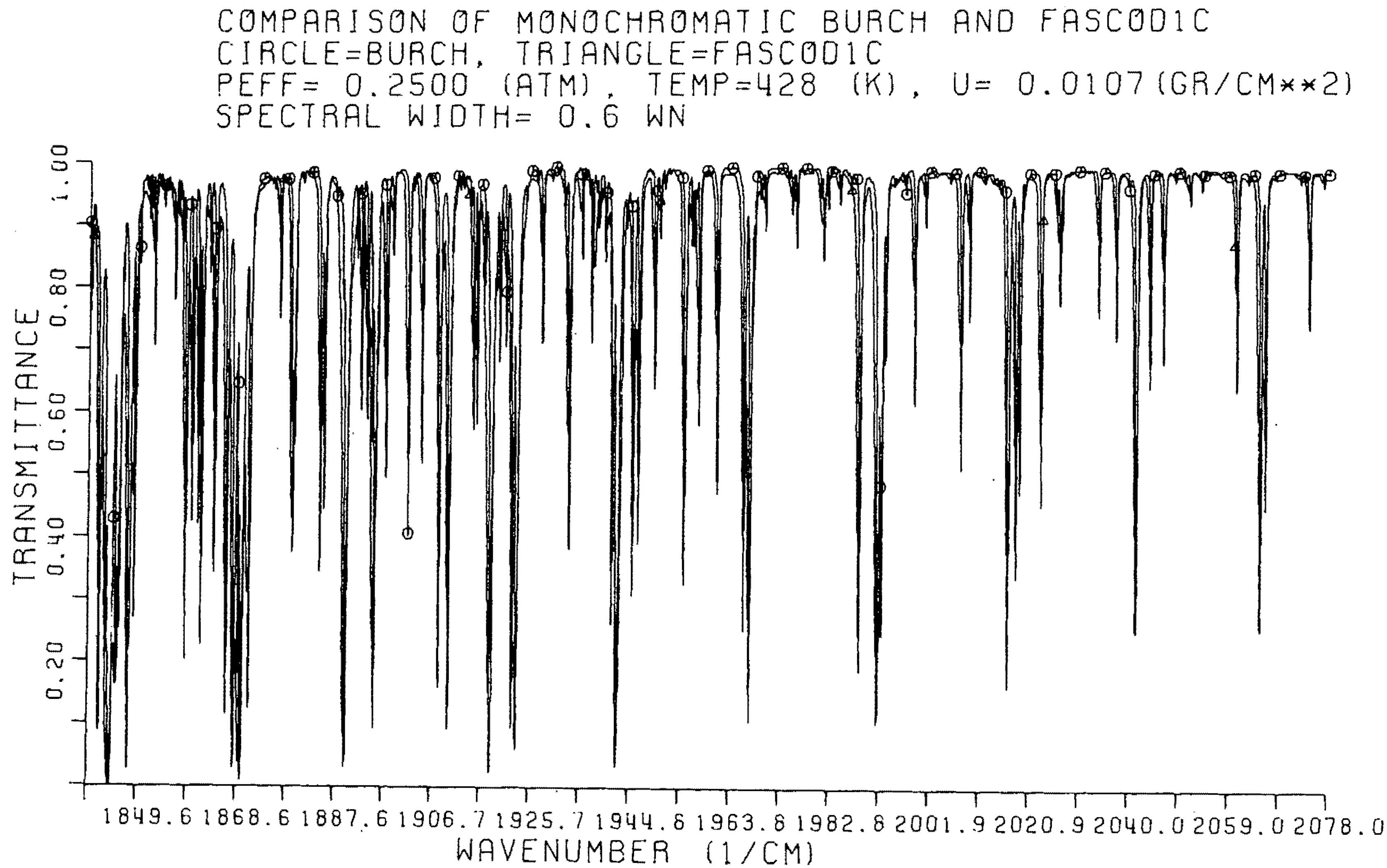

COMPARISON OF MONOCHROMATIC BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.2500 (ATM), TEMP=428 (K), U= 0.0107(GR/CM**2)
SPECTRAL WIDTH= 0.6 WN
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1849.6
1868.6
1887.6
1906.7
1925.7
1944.6
1963.6
1982.6
2001.9
2020.9
2040.0
2059.0
2078.0
WAVENUMBER (1/CM)

Figure D2a

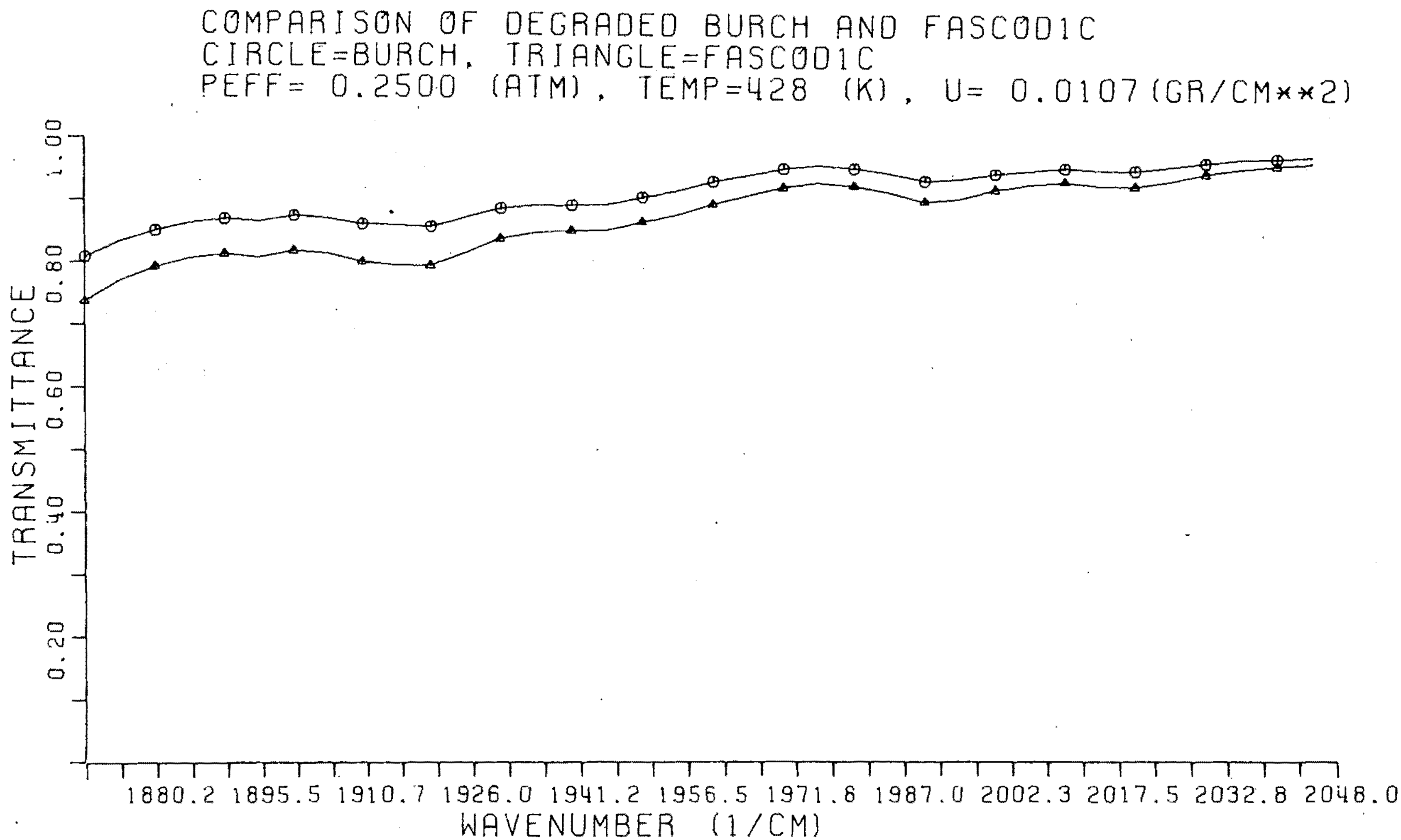

COMPARISON OF DEGRADED BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.2500 (ATM), TEMP=428 (K), U= 0.0107(GR/CM**2)
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1880.2 1895.5 1910.7 1926.0 1941.2 1956.5 1971.8 1987.0 2002.3 2017.5 2032.8 2048.0
WAVENUMBER (1/CM)

Figure D2b

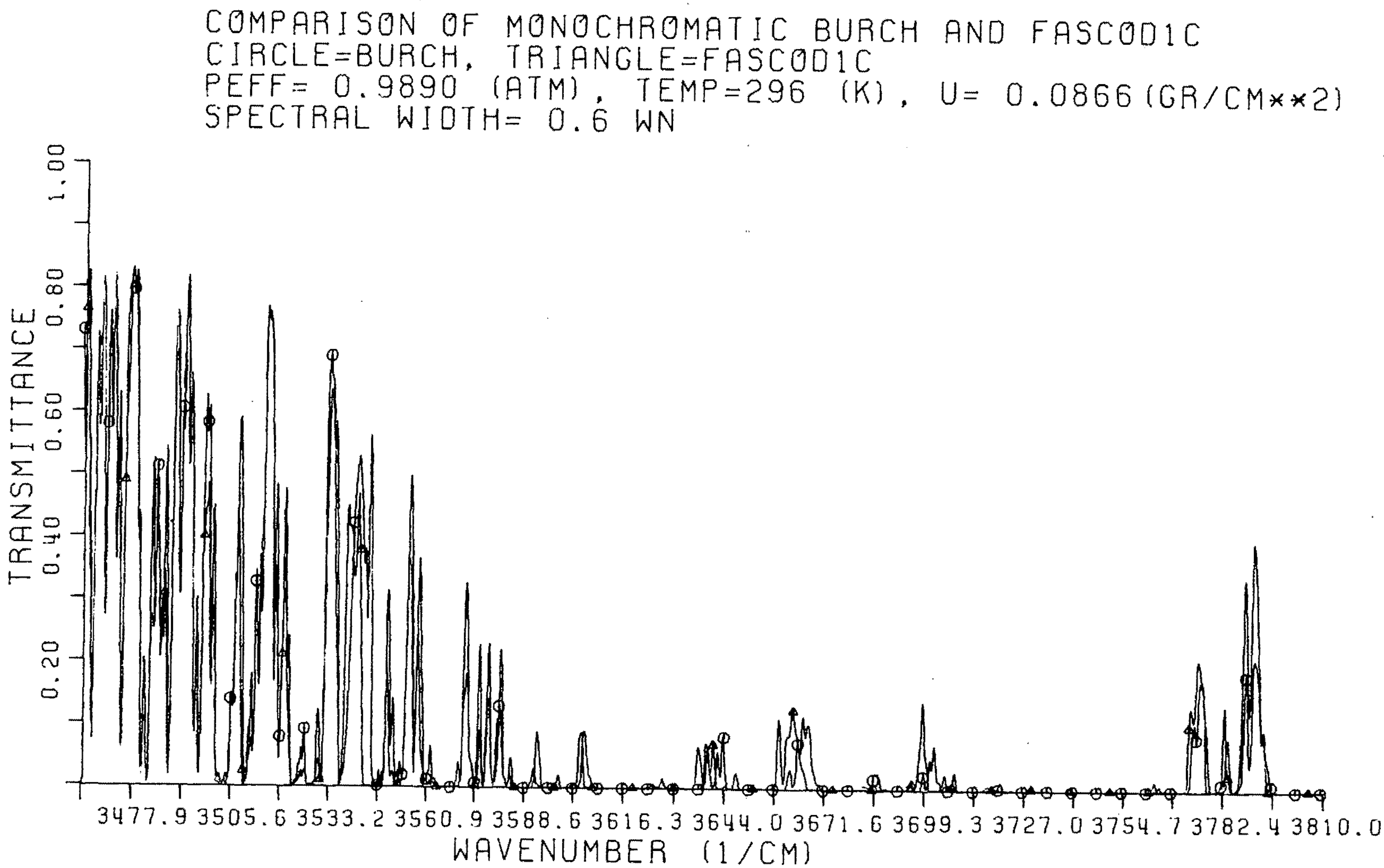

COMPARISON OF MONOCHROMATIC BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.9890 (ATM), TEMP=296 (K), U= 0.0866(GR/CM**2)
SPECTRAL WIDTH= 0.6 WN
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
3477.9 3505.6 3533.2 3560.9 3588.6 3616.3 3644.0 3671.6 3699.3 3727.0 3754.7 3782.4 3810.0
WAVENUMBER (1/CM)

Figure D3a

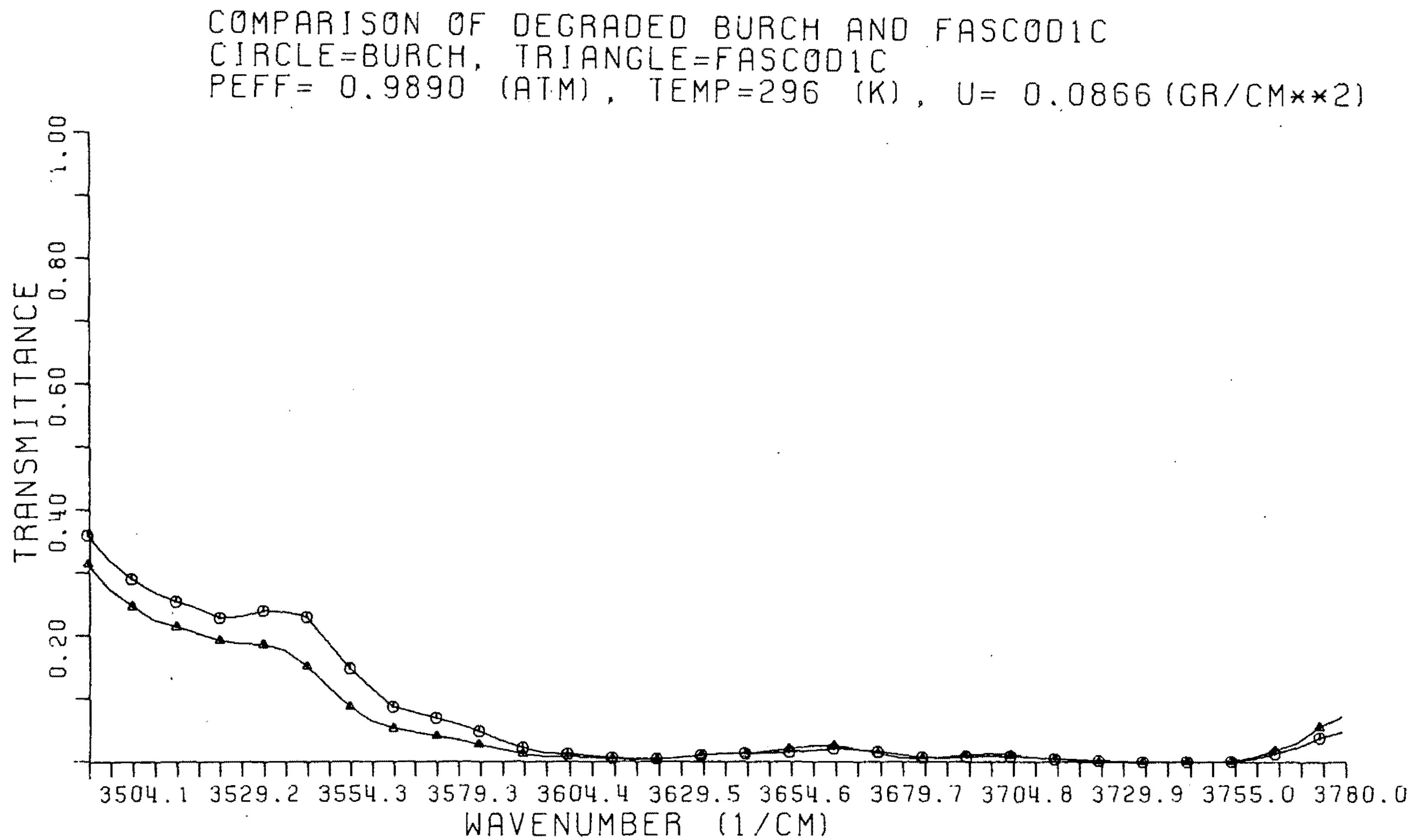

COMPARISON OF DEGRADED BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.9890 (ATM), TEMP=296 (K), U= 0.0866 (GR/CM**2)
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
3504.1
3529.2
3554.3
3579.3
3604.4
3629.5
3654.6
3679.7
3704.8
3729.9
3755.0
3780.0
WAVENUMBER (1/CM)

Figure D3b

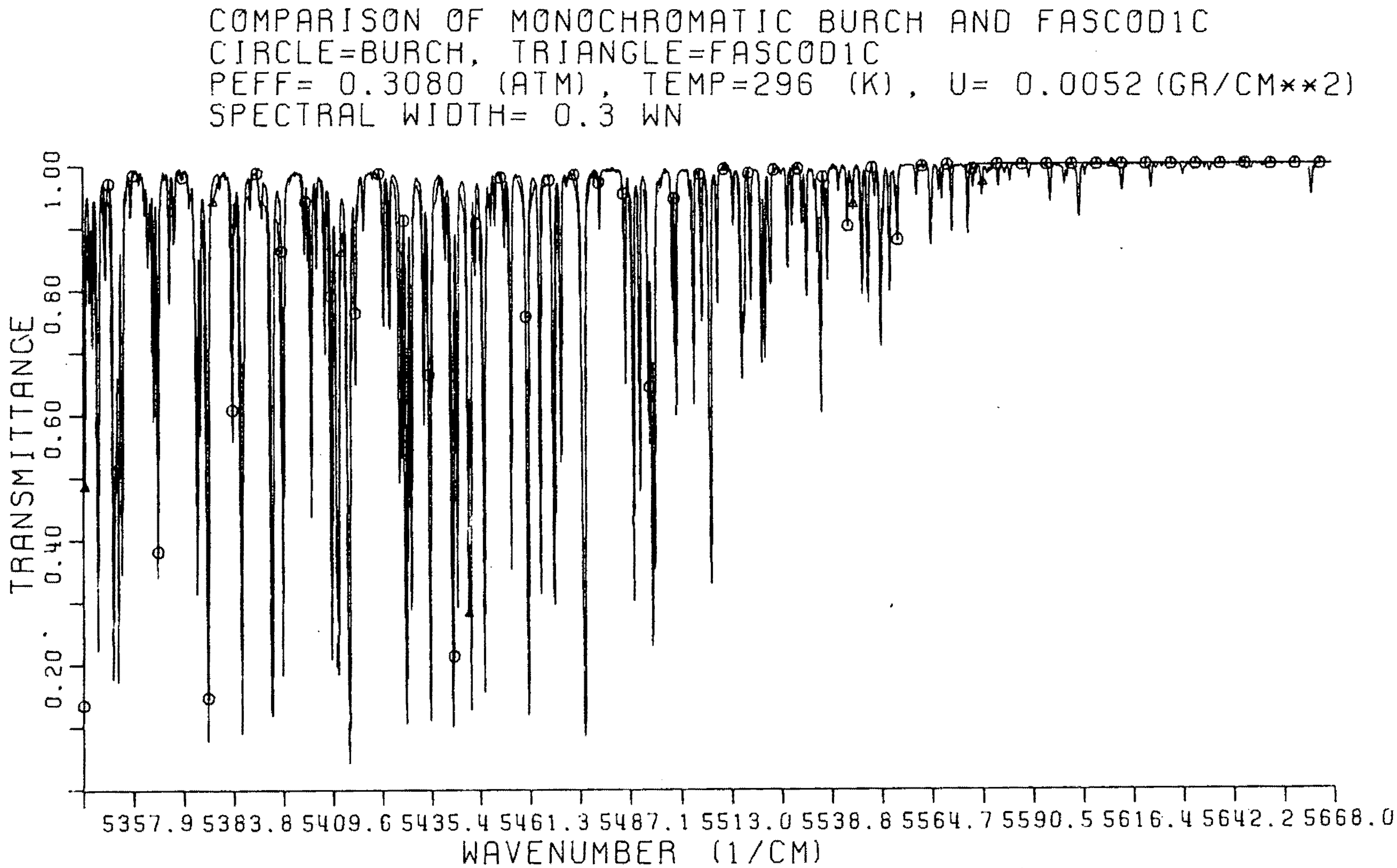

COMPARISON OF MONOCHROMATIC BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.3080 (ATM), TEMP=296 (K), U= 0.0052 (GR/CM**2)
SPECTRAL WIDTH= 0.3 WN
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
5357.9
5383.8
5409.6
5435.4
5461.3
5487.1
5513.0
5538.8
5564.7
5590.5
5616.4
5642.2
5668.0
WAVENUMBER (1/CM)

Figure D4a

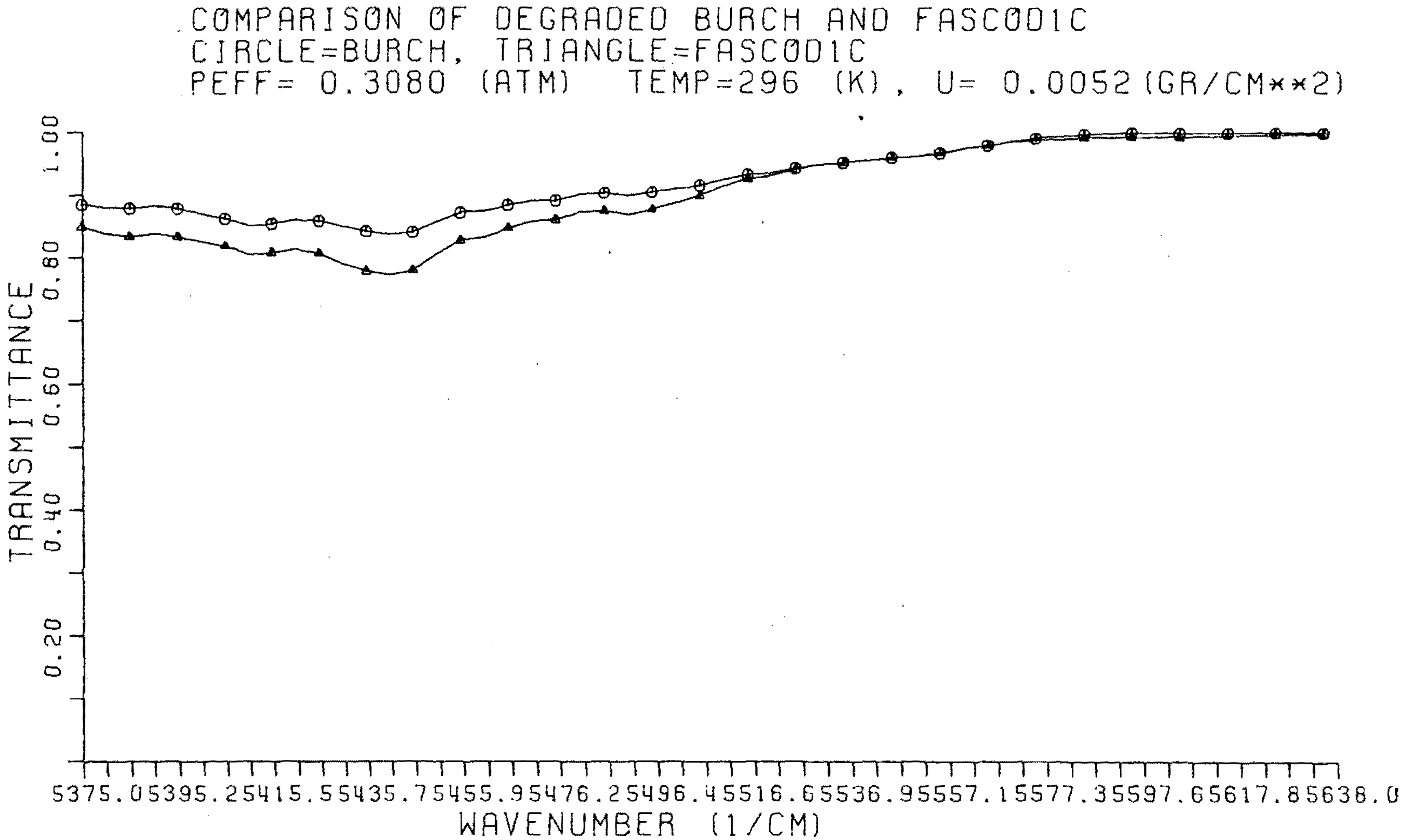

COMPARISON OF DEGRADED BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.3080 (ATM) TEMP=296 (K), U= 0.0052(GR/CM**2)
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
5375.0 5395.2 5415.5 5435.7 5455.9 5476.2 5496.4 5516.6 5536.9 5557.1 5577.3 5597.6 5617.8 5638.0
WAVENUMBER (1/CM)

Figure D4b

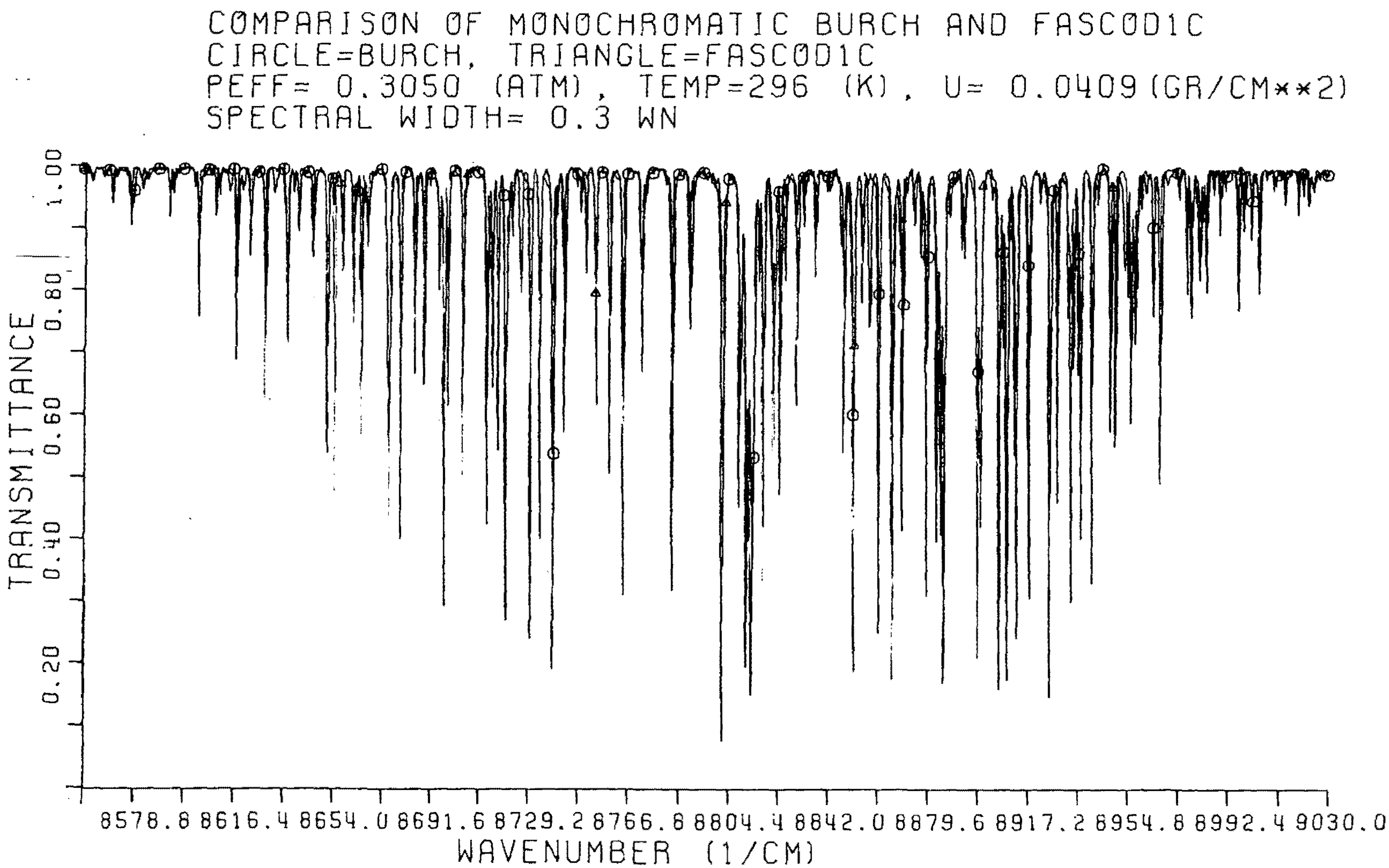

COMPARISON OF MONOCHROMATIC BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.3050 (ATM), TEMP=296 (K), U= 0.0409(GR/CM**2)
SPECTRAL WIDTH= 0.3 WN
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
8578.8
8616.4
8654.0
8691.6
8729.2
8766.8
8804.4
8842.0
8879.6
8917.2
8954.8
8992.4
9030.0
WAVENUMBER (1/CM)

Figure D5a

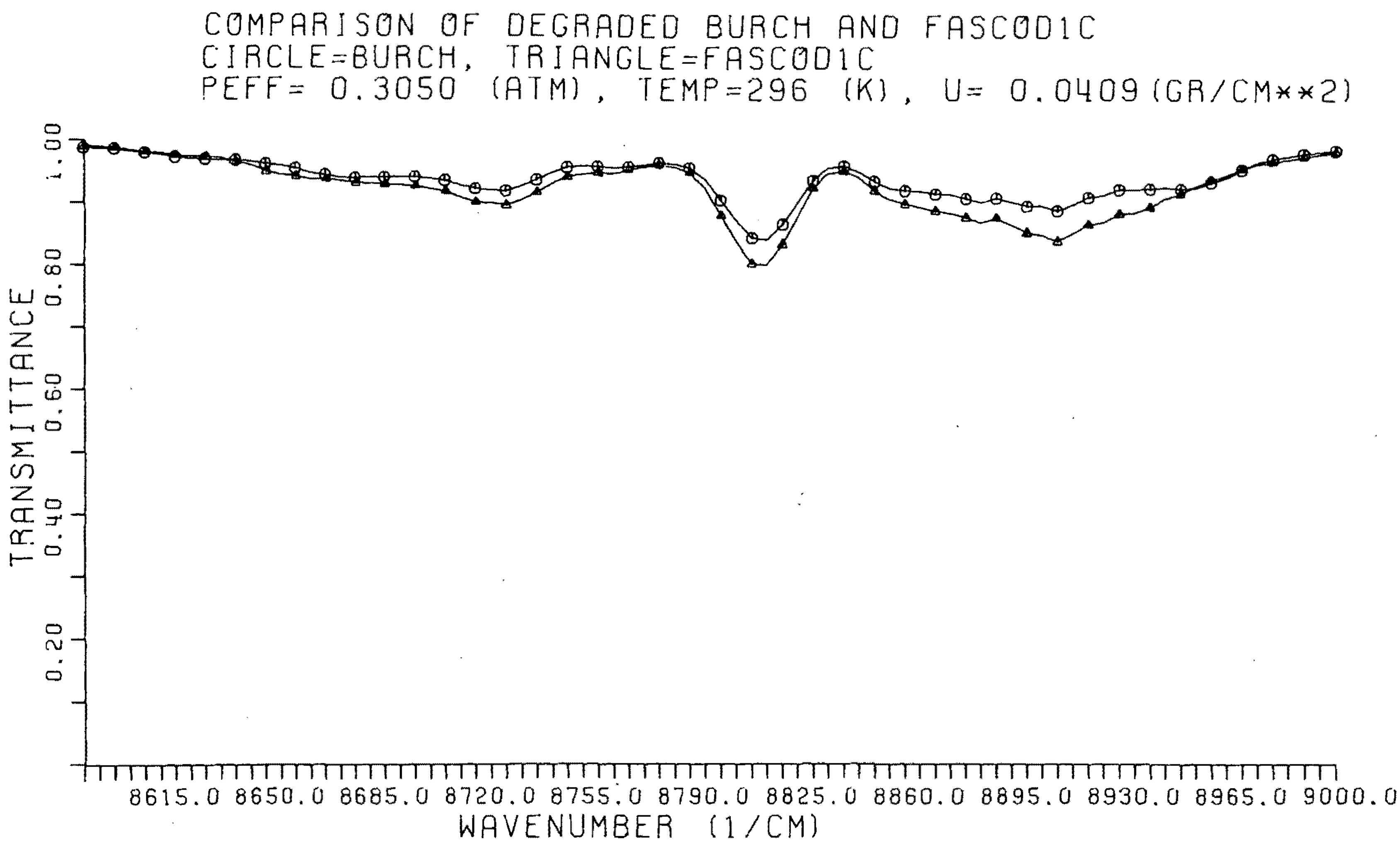

COMPARISON OF DEGRADED BURCH AND FASCOD1C
CIRCLE=BURCH, TRIANGLE=FASCOD1C
PEFF= 0.3050 (ATM), TEMP=296 (K), U= 0.0409(GR/CM**2)
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
8615.0 8650.0 8685.0 8720.0 8755.0 8790.0 8825.0 8860.0 8895.0 8930.0 8965.0 9000.0
WAVENUMBER (1/CM)

Figure D5b

APPENDIX E

Comparison Between Degraded Line-By-Line and Proposed Model Calculated Transmittance for H_2O and O_3.

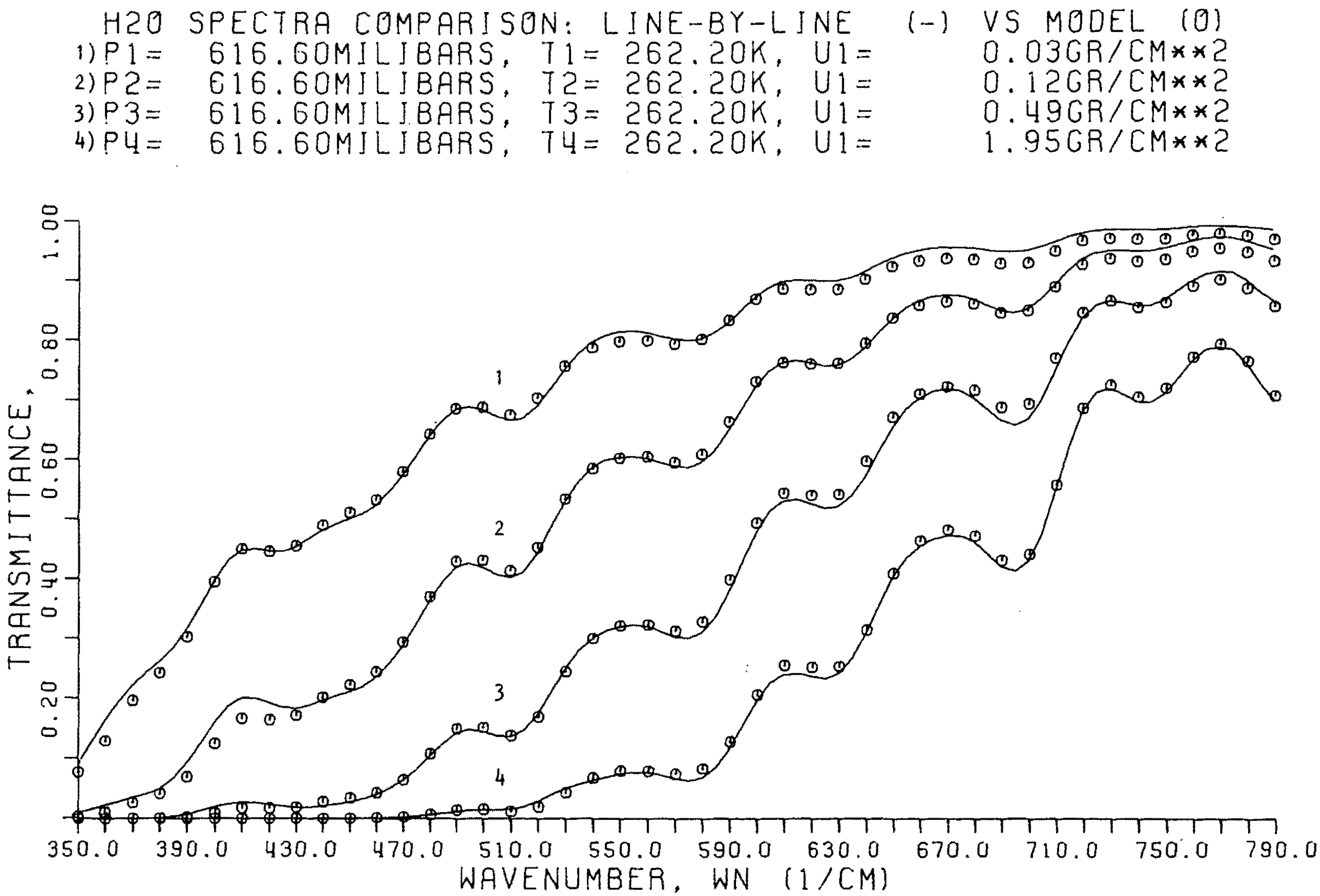

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1)P1= 616.60MILIBARS, T1= 262.20K, U1= 0.03GR/CM**2
2)P2= 616.60MILIBARS, T2= 262.20K, U1= 0.12GR/CM**2
3)P3= 616.60MILIBARS, T3= 262.20K, U1= 0.49GR/CM**2
4)P4= 616.60MILIBARS, T4= 262.20K, U1= 1.95GR/CM**2
TRANSMITTANCE,
0.20
0.40
0.60
0.80
1.00
1
2
3
4
350.0
390.0
430.0
470.0
510.0
550.0
590.0
630.0
670.0
710.0
750.0
790.0
WAVENUMBER, WN (1/CM)

Figure E1

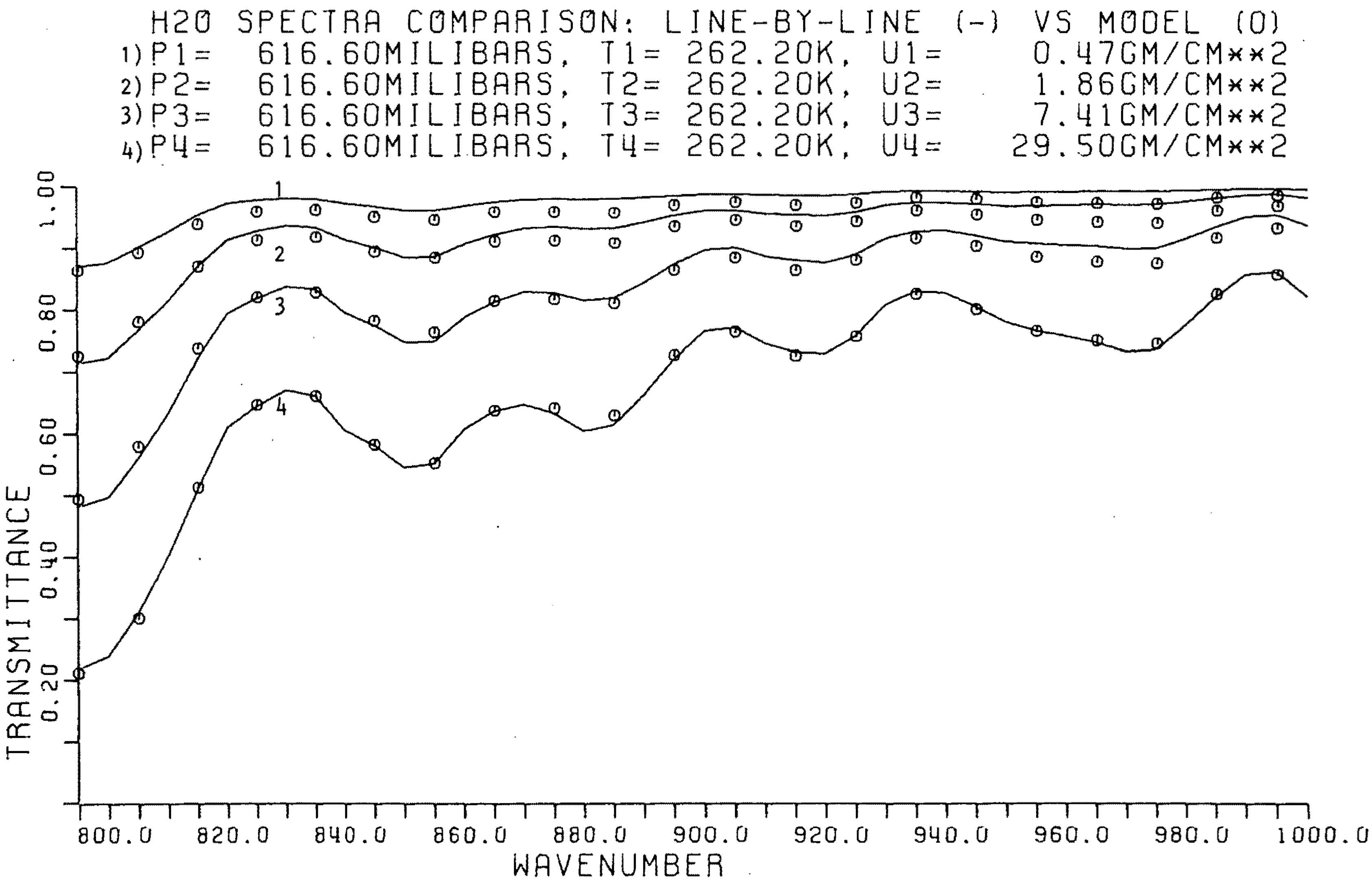

H20 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 616.60MILIBARS, T1= 262.20K, U1= 0.47GM/CM**2
2) P2= 616.60MILIBARS, T2= 262.20K, U2= 1.86GM/CM**2
3) P3= 616.60MILIBARS, T3= 262.20K, U3= 7.41GM/CM**2
4) P4= 616.60MILIBARS, T4= 262.20K, U4= 29.50GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
800.0
820.0
840.0
860.0
880.0
900.0
920.0
940.0
960.0
980.0
1000.0
WAVENUMBER

Figure E2

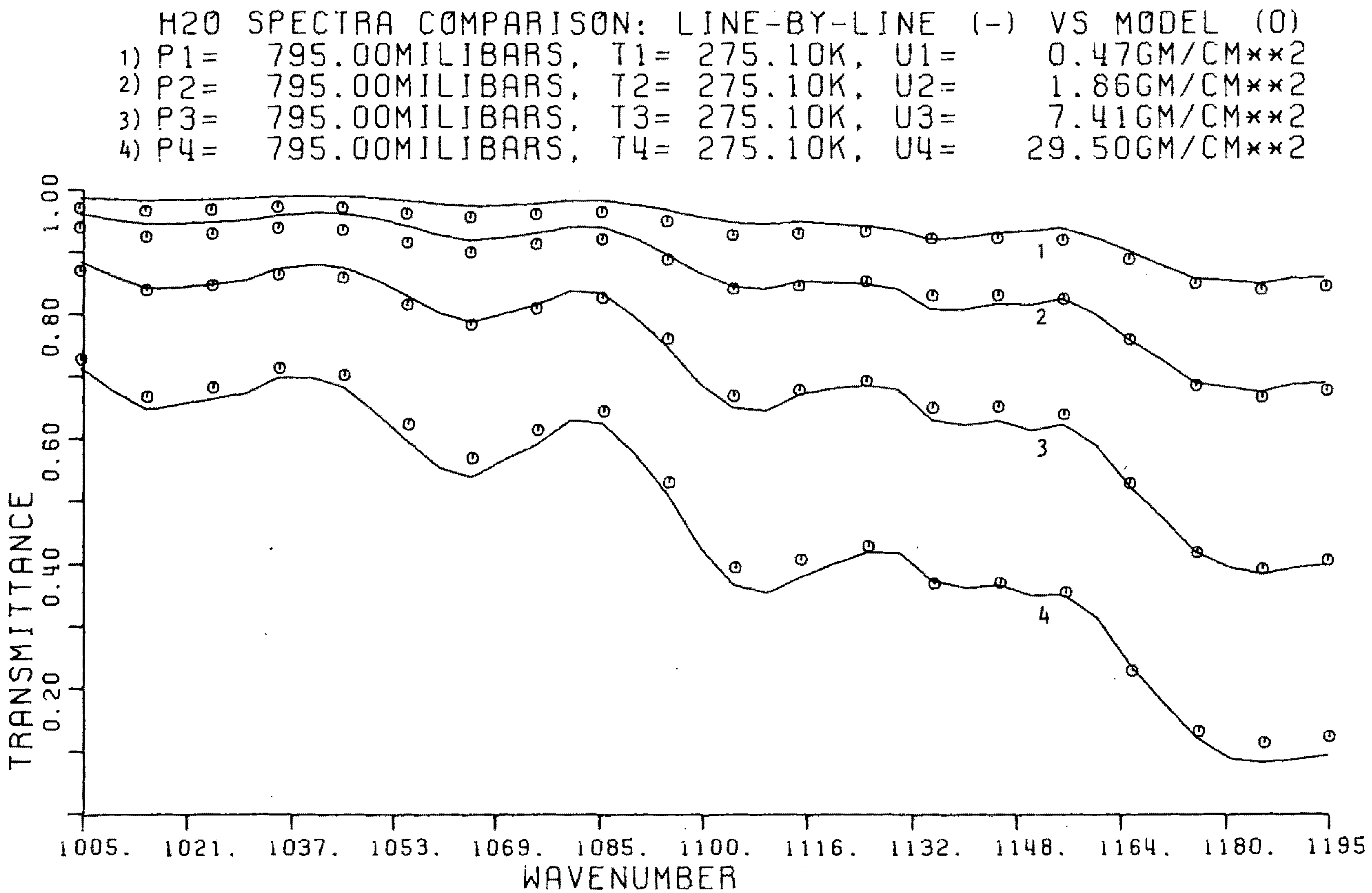

H20 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00MILIBARS, T1= 275.10K, U1= 0.47GM/CM**2
2) P2= 795.00MILIBARS, T2= 275.10K, U2= 1.86GM/CM**2
3) P3= 795.00MILIBARS, T3= 275.10K, U3= 7.41GM/CM**2
4) P4= 795.00MILIBARS, T4= 275.10K, U4= 29.50GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
1005. 1021. 1037. 1053. 1069. 1085. 1100. 1116. 1132. 1148. 1164. 1180. 1195.
WAVENUMBER

Figure E3

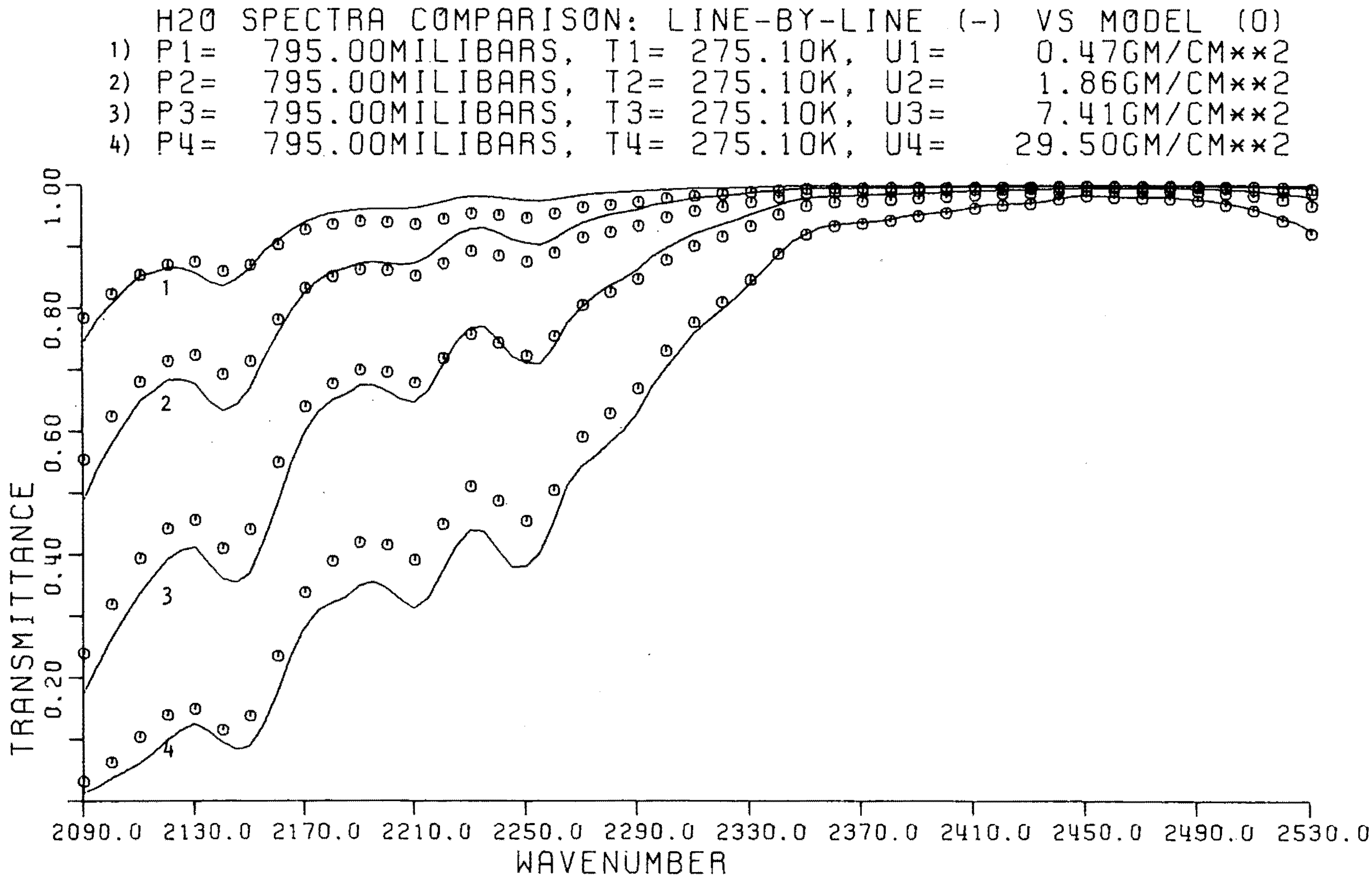

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00MILIBARS, T1= 275.10K, U1= 0.47GM/CM**2
2) P2= 795.00MILIBARS, T2= 275.10K, U2= 1.86GM/CM**2
3) P3= 795.00MILIBARS, T3= 275.10K, U3= 7.41GM/CM**2
4) P4= 795.00MILIBARS, T4= 275.10K, U4= 29.50GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
2090.0
2130.0
2170.0
2210.0
2250.0
2290.0
2330.0
2370.0
2410.0
2450.0
2490.0
2530.0
WAVENUMBER

Figure E4

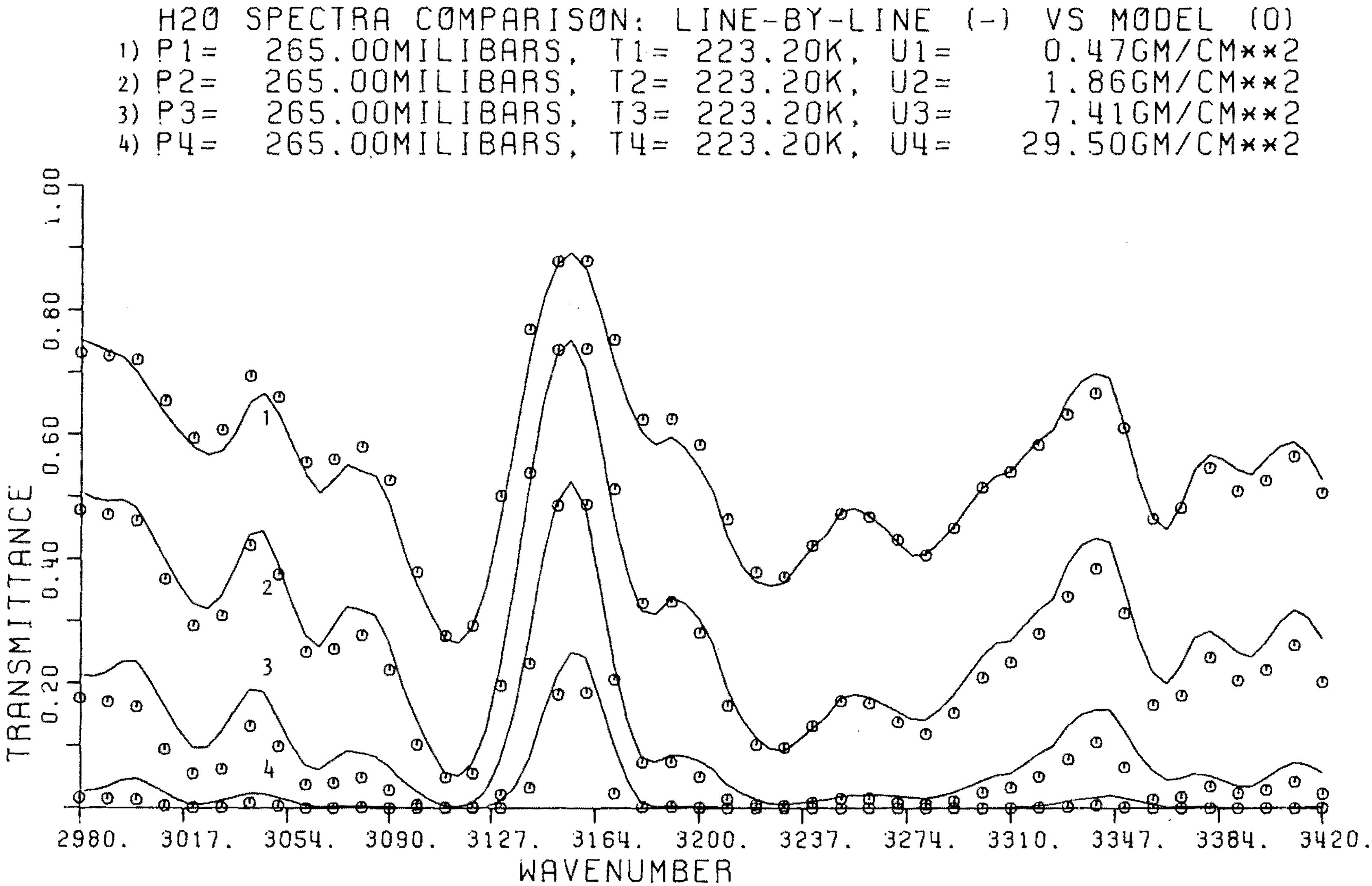

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 265.00MILIBARS, T1= 223.20K, U1= 0.47GM/CM**2
2) P2= 265.00MILIBARS, T2= 223.20K, U2= 1.86GM/CM**2
3) P3= 265.00MILIBARS, T3= 223.20K, U3= 7.41GM/CM**2
4) P4= 265.00MILIBARS, T4= 223.20K, U4= 29.50GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
2980.
3017.
3054.
3090.
3127.
3164.
3200.
3237.
3274.
3310.
3347.
3384.
3420.
WAVENUMBER

Figure E5

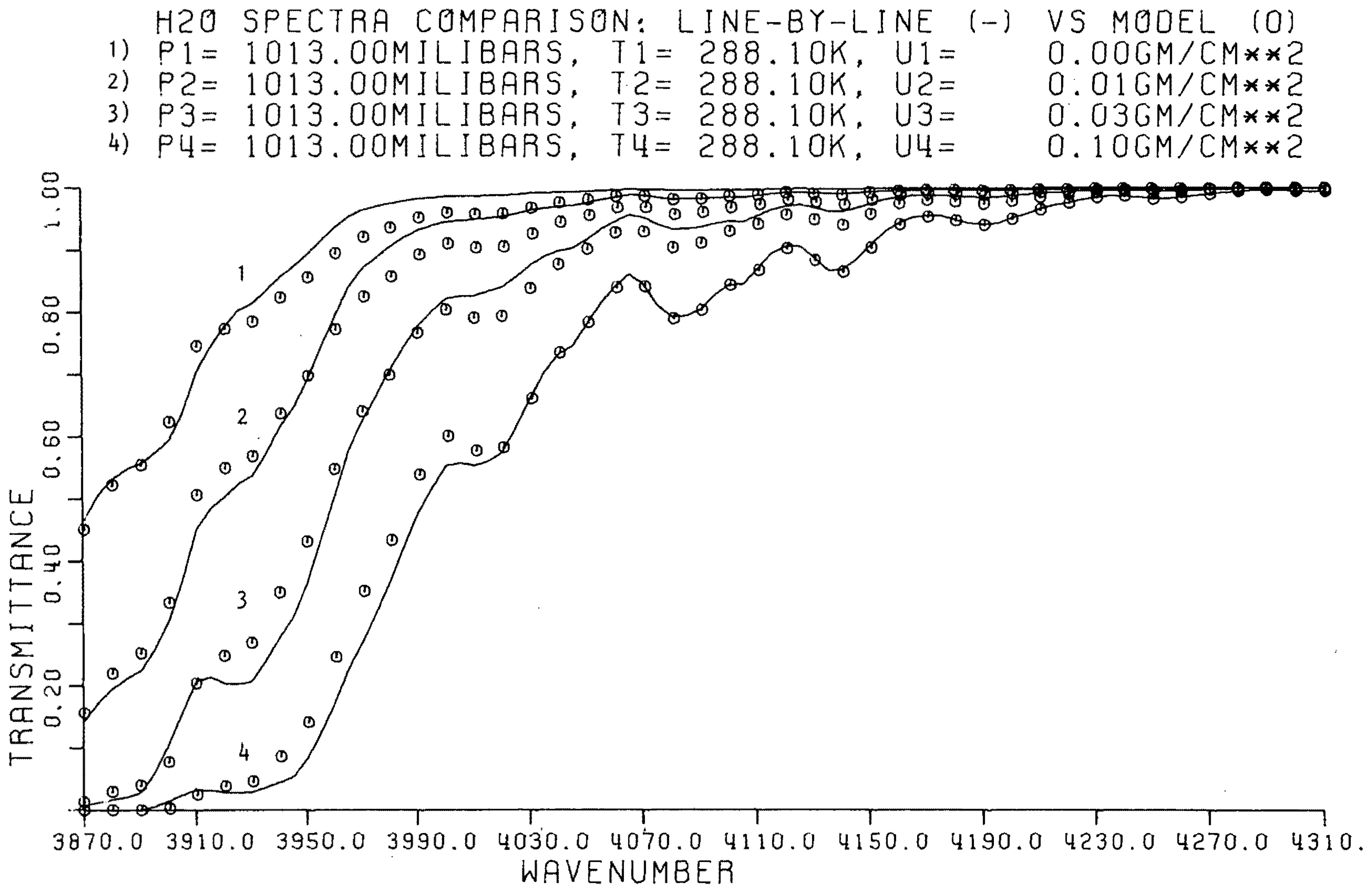

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 1013.00MILIBARS, T1= 288.10K, U1= 0.00GM/CM**2
2) P2= 1013.00MILIBARS, T2= 288.10K, U2= 0.01GM/CM**2
3) P3= 1013.00MILIBARS, T3= 288.10K, U3= 0.03GM/CM**2
4) P4= 1013.00MILIBARS, T4= 288.10K, U4= 0.10GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
3870.0
3910.0
3950.0
3990.0
4030.0
4070.0
4110.0
4150.0
4190.0
4230.0
4270.0
4310.0
WAVENUMBER

Figure E6

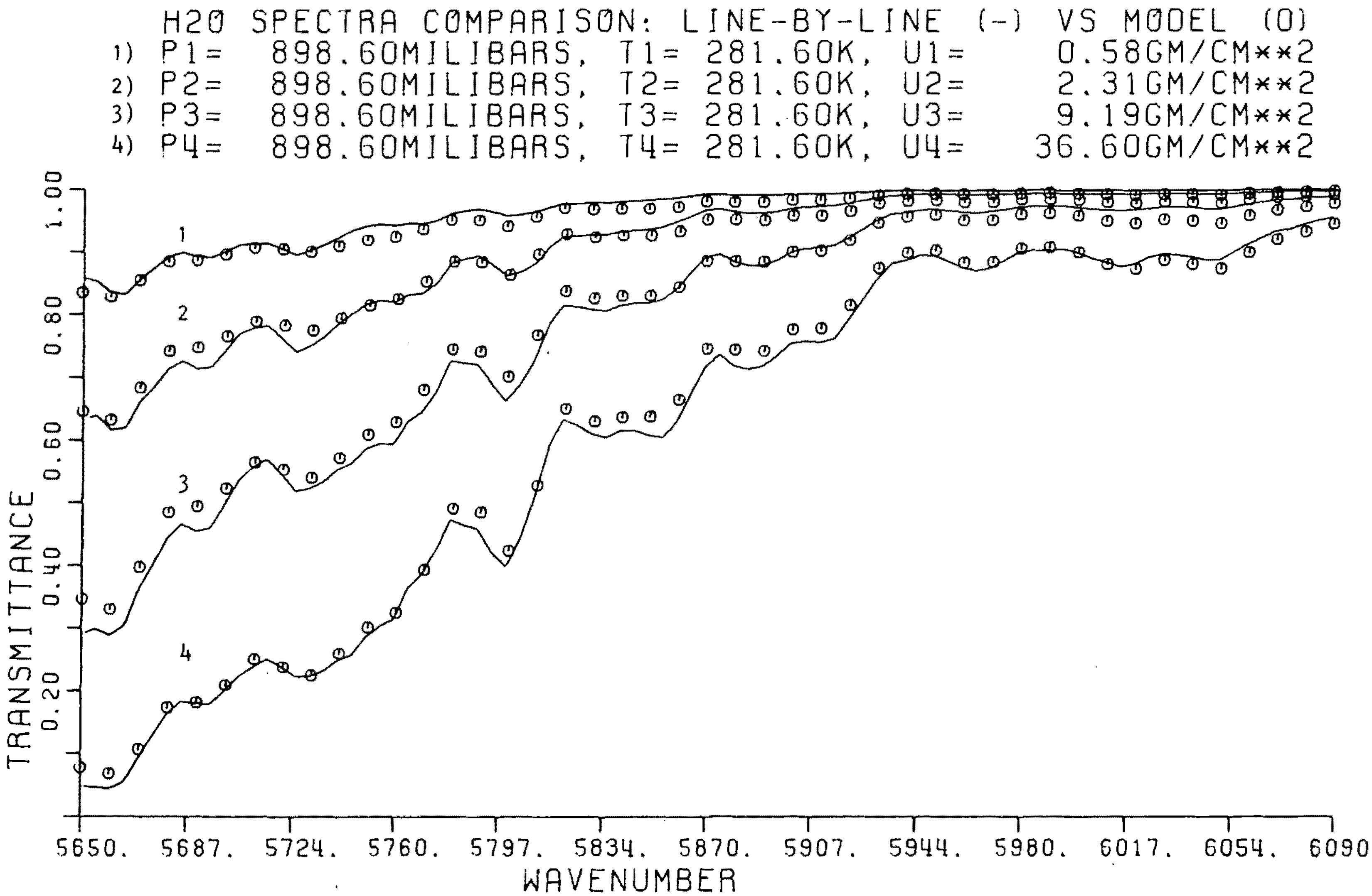

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60MILIBARS, T1= 281.60K, U1= 0.58GM/CM**2
2) P2= 898.60MILIBARS, T2= 281.60K, U2= 2.31GM/CM**2
3) P3= 898.60MILIBARS, T3= 281.60K, U3= 9.19GM/CM**2
4) P4= 898.60MILIBARS, T4= 281.60K, U4= 36.60GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
5650.
5687.
5724.
5760.
5797.
5834.
5870.
5907.
5944.
5980.
6017.
6054.
6090.
WAVENUMBER

Figure E7

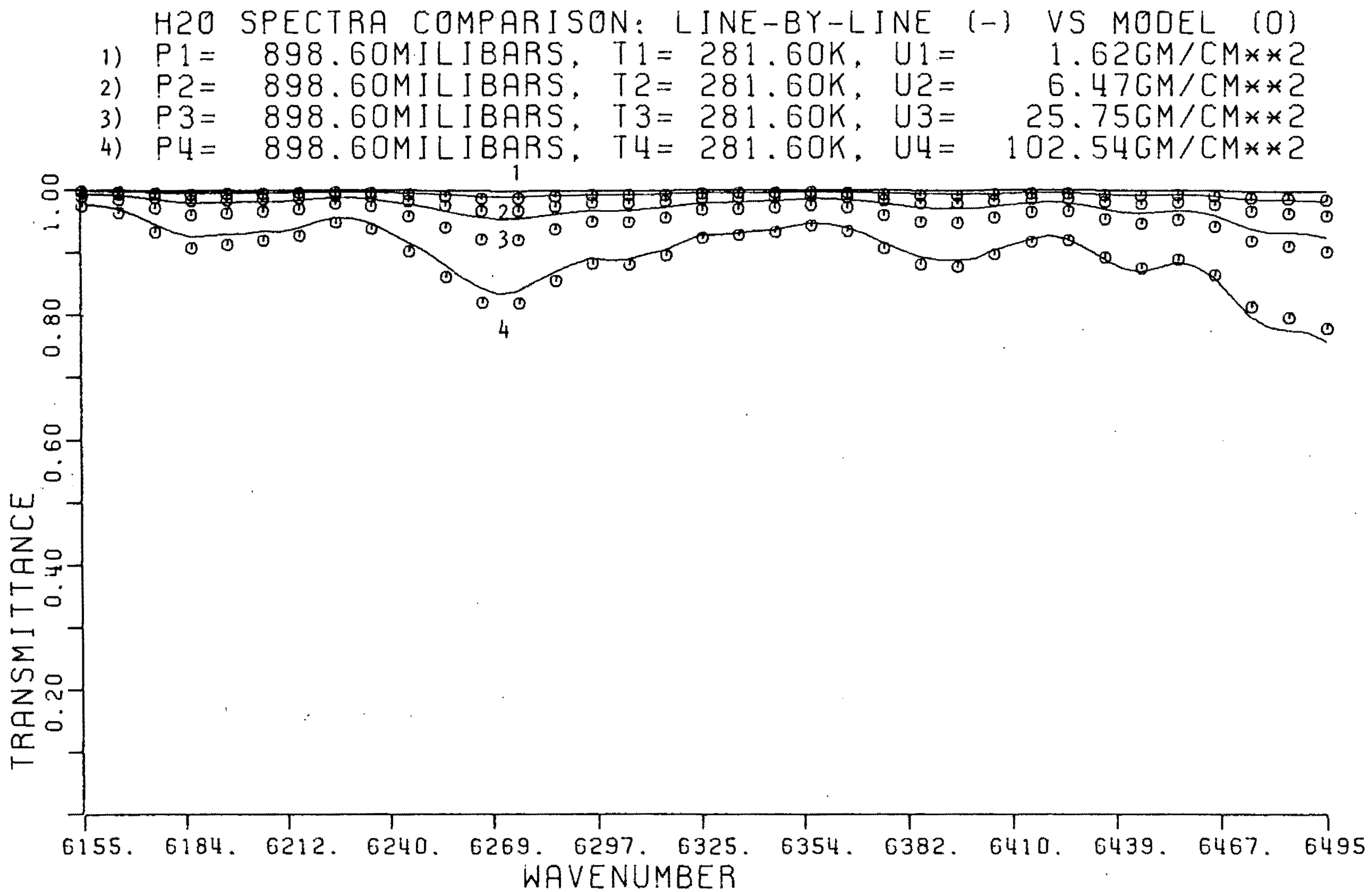
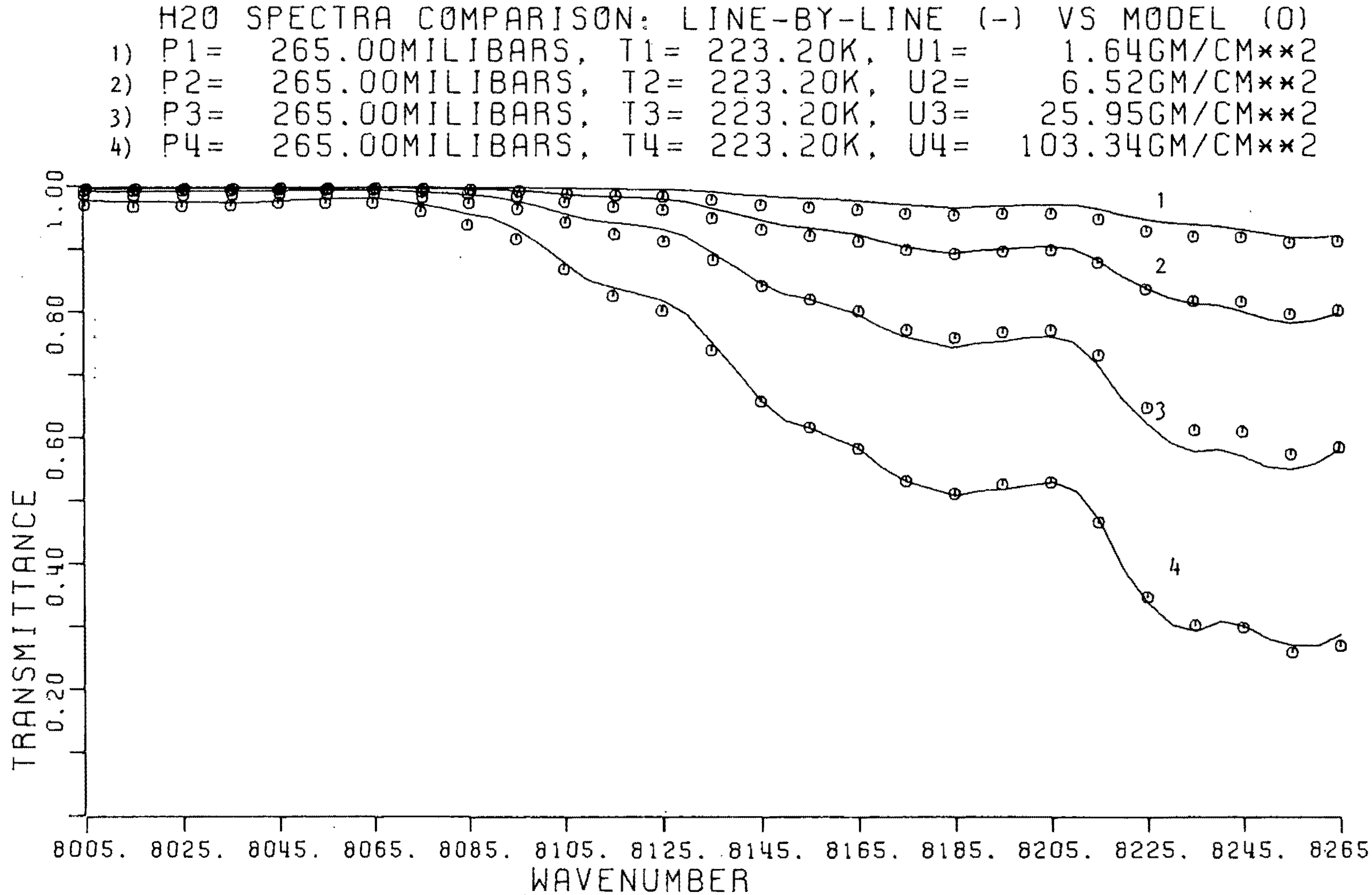

H20 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60MILIBARS, T1= 281.60K, U1= 1.62GM/CM**2
2) P2= 898.60MILIBARS, T2= 281.60K, U2= 6.47GM/CM**2
3) P3= 898.60MILIBARS, T3= 281.60K, U3= 25.75GM/CM**2
4) P4= 898.60MILIBARS, T4= 281.60K, U4= 102.54GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
6155.
6184.
6212.
6240.
6269.
6297.
6325.
6354.
6382.
6410.
6439.
6467.
6495.
WAVENUMBER

Figure E8



H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 265.00MILIBARS, T1= 223.20K, U1= 1.64GM/CM**2
2) P2= 265.00MILIBARS, T2= 223.20K, U2= 6.52GM/CM**2
3) P3= 265.00MILIBARS, T3= 223.20K, U3= 25.95GM/CM**2
4) P4= 265.00MILIBARS, T4= 223.20K, U4= 103.34GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
WAVENUMBER
8005.
8025.
8045.
8065.
8085.
8105.
8125.
8145.
8165.
8185.
8205.
8225.
8245.
8265.
1
2
3
4

Figure E9

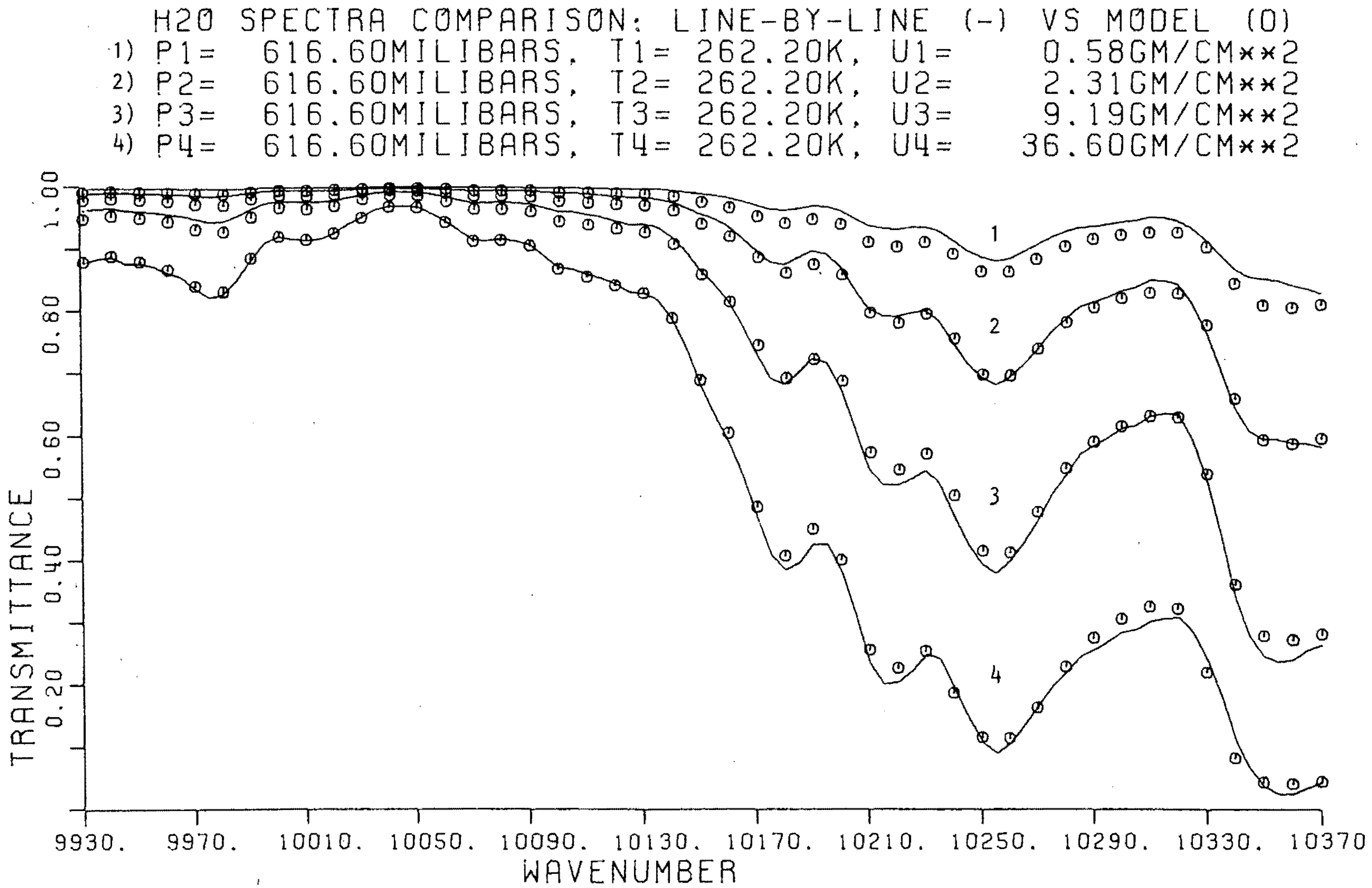

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 616.60MILIBARS, T1= 262.20K, U1= 0.58GM/CM**2
2) P2= 616.60MILIBARS, T2= 262.20K, U2= 2.31GM/CM**2
3) P3= 616.60MILIBARS, T3= 262.20K, U3= 9.19GM/CM**2
4) P4= 616.60MILIBARS, T4= 262.20K, U4= 36.60GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
9930.
9970.
10010.
10050.
10090.
10130.
10170.
10210.
10250.
10290.
10330.
10370.
WAVENUMBER

Figure E10

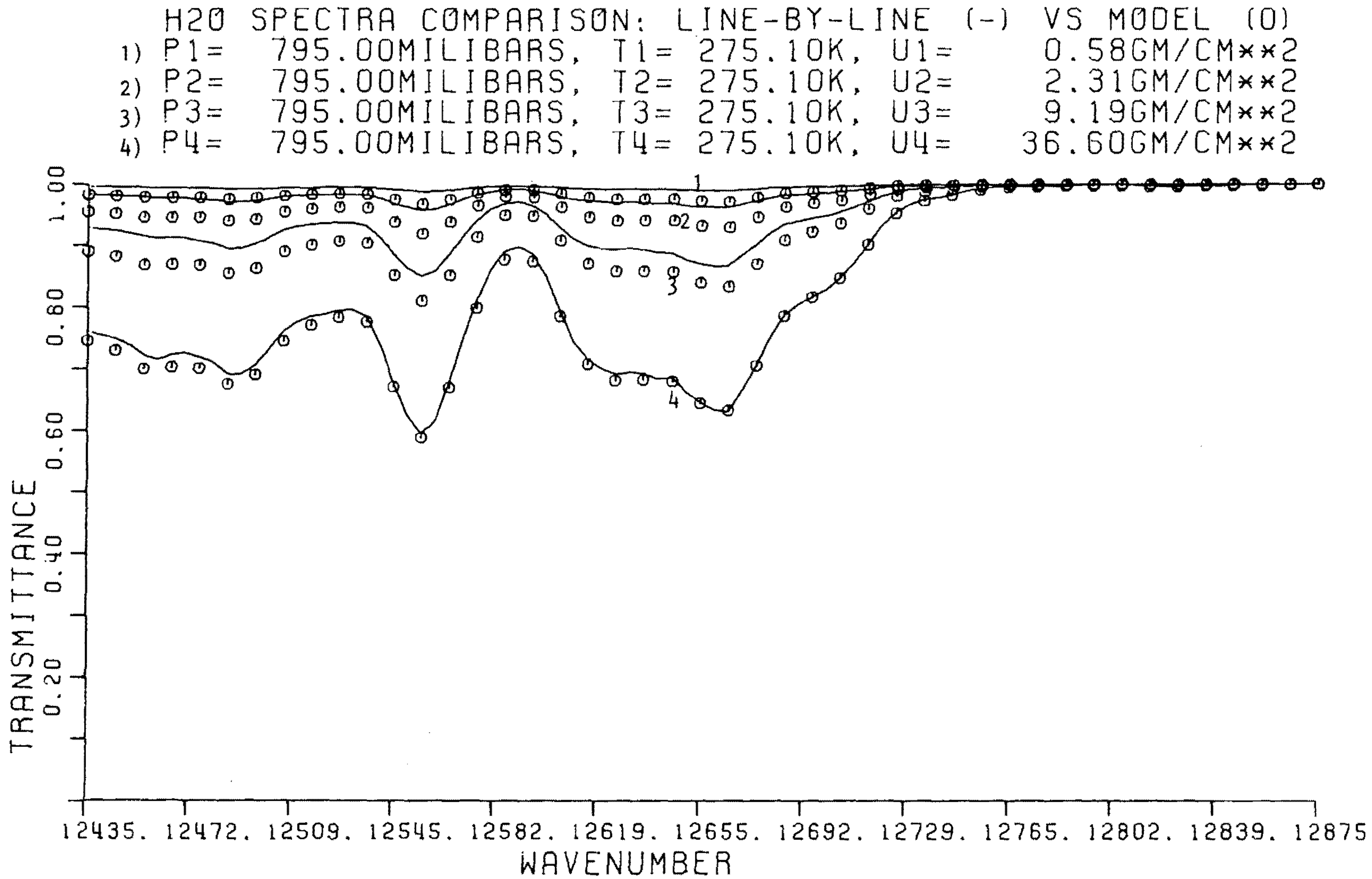

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00MILIBARS, T1= 275.10K, U1= 0.58GM/CM**2
2) P2= 795.00MILIBARS, T2= 275.10K, U2= 2.31GM/CM**2
3) P3= 795.00MILIBARS, T3= 275.10K, U3= 9.19GM/CM**2
4) P4= 795.00MILIBARS, T4= 275.10K, U4= 36.60GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
12435. 12472. 12509. 12545. 12582. 12619. 12655. 12692. 12729. 12765. 12802. 12839. 12875.
WAVENUMBER

Figure E11

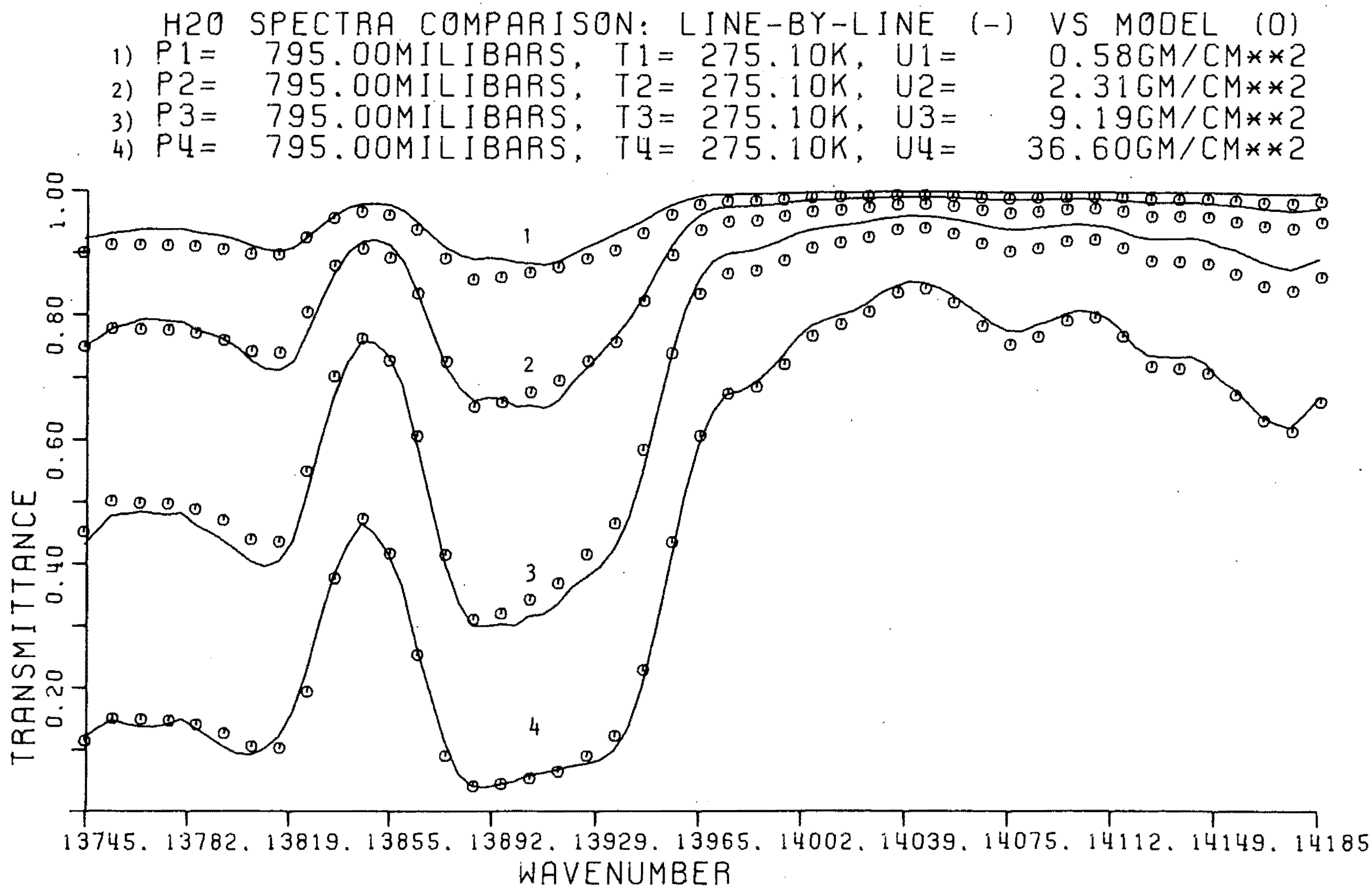

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00MILIBARS, T1= 275.10K, U1= 0.58GM/CM**2
2) P2= 795.00MILIBARS, T2= 275.10K, U2= 2.31GM/CM**2
3) P3= 795.00MILIBARS, T3= 275.10K, U3= 9.19GM/CM**2
4) P4= 795.00MILIBARS, T4= 275.10K, U4= 36.60GM/CM**2
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
13745. 13782. 13819. 13855. 13892. 13929. 13965. 14002. 14039. 14075. 14112. 14149. 14185.
WAVENUMBER

Figure E12

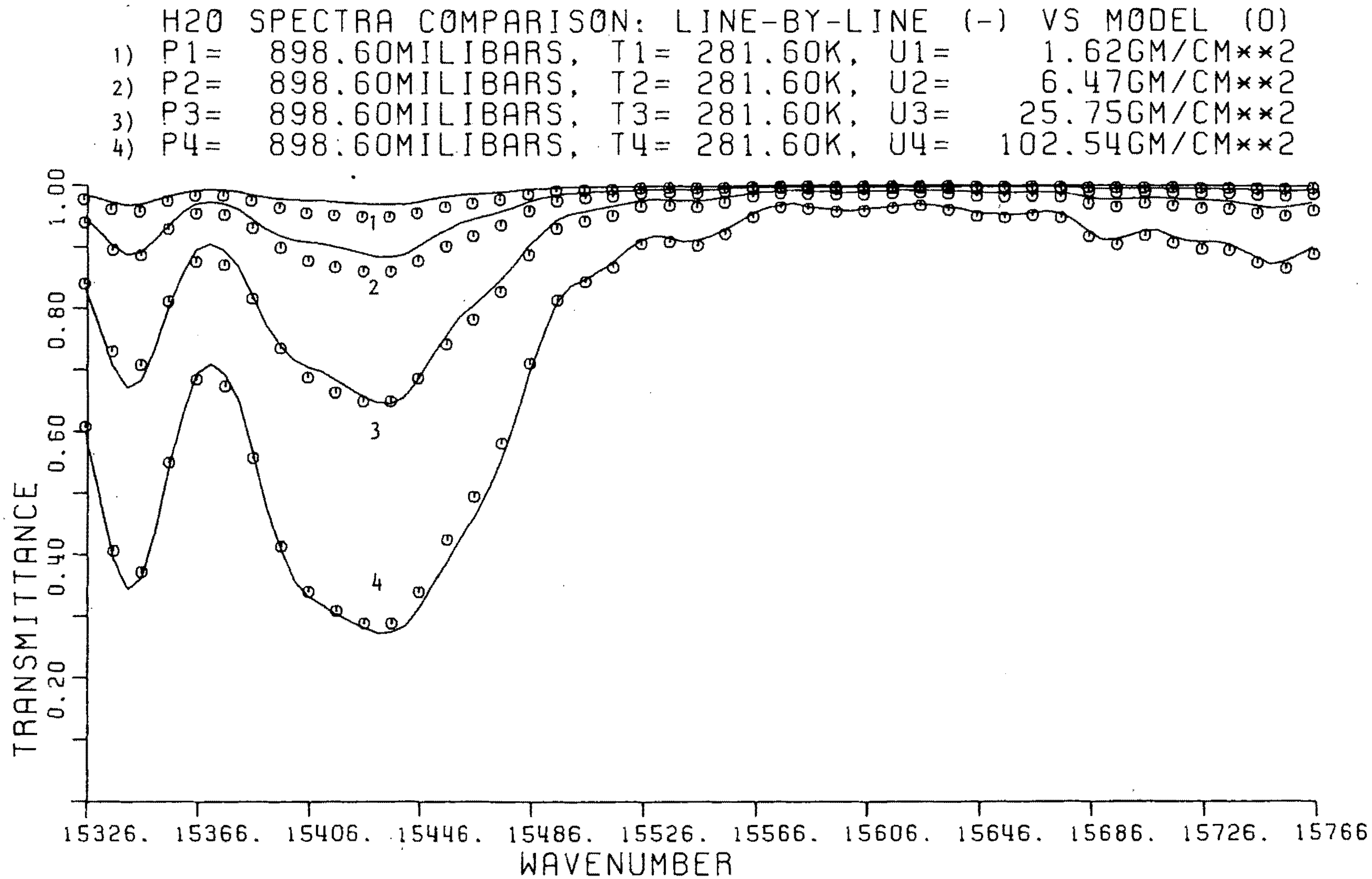

H20 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60MILIBARS, T1= 281.60K, U1= 1.62GM/CM**2
2) P2= 898.60MILIBARS, T2= 281.60K, U2= 6.47GM/CM**2
3) P3= 898.60MILIBARS, T3= 281.60K, U3= 25.75GM/CM**2
4) P4= 898.60MILIBARS, T4= 281.60K, U4= 102.54GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
15326. 15366. 15406. 15446. 15486. 15526. 15566. 15606. 15646. 15686. 15726. 15766.
WAVENUMBER

Figure E13

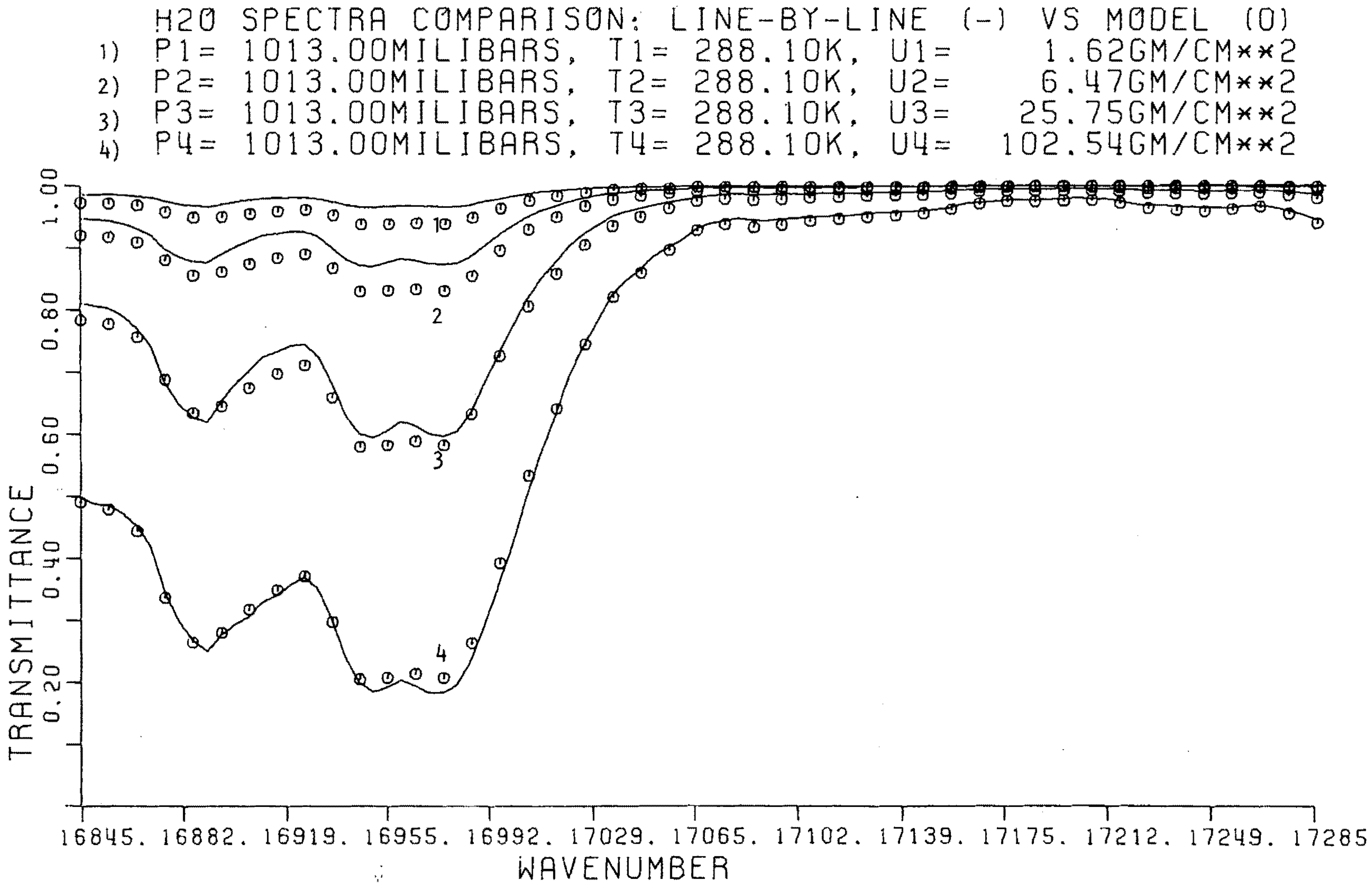

H2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 1013.00MILIBARS, T1= 288.10K, U1= 1.62GM/CM**2
2) P2= 1013.00MILIBARS, T2= 288.10K, U2= 6.47GM/CM**2
3) P3= 1013.00MILIBARS, T3= 288.10K, U3= 25.75GM/CM**2
4) P4= 1013.00MILIBARS, T4= 288.10K, U4= 102.54GM/CM**2
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
16845. 16882. 16919. 16955. 16992. 17029. 17065. 17102. 17139. 17175. 17212. 17249. 17285.
WAVENUMBER

Figure E14

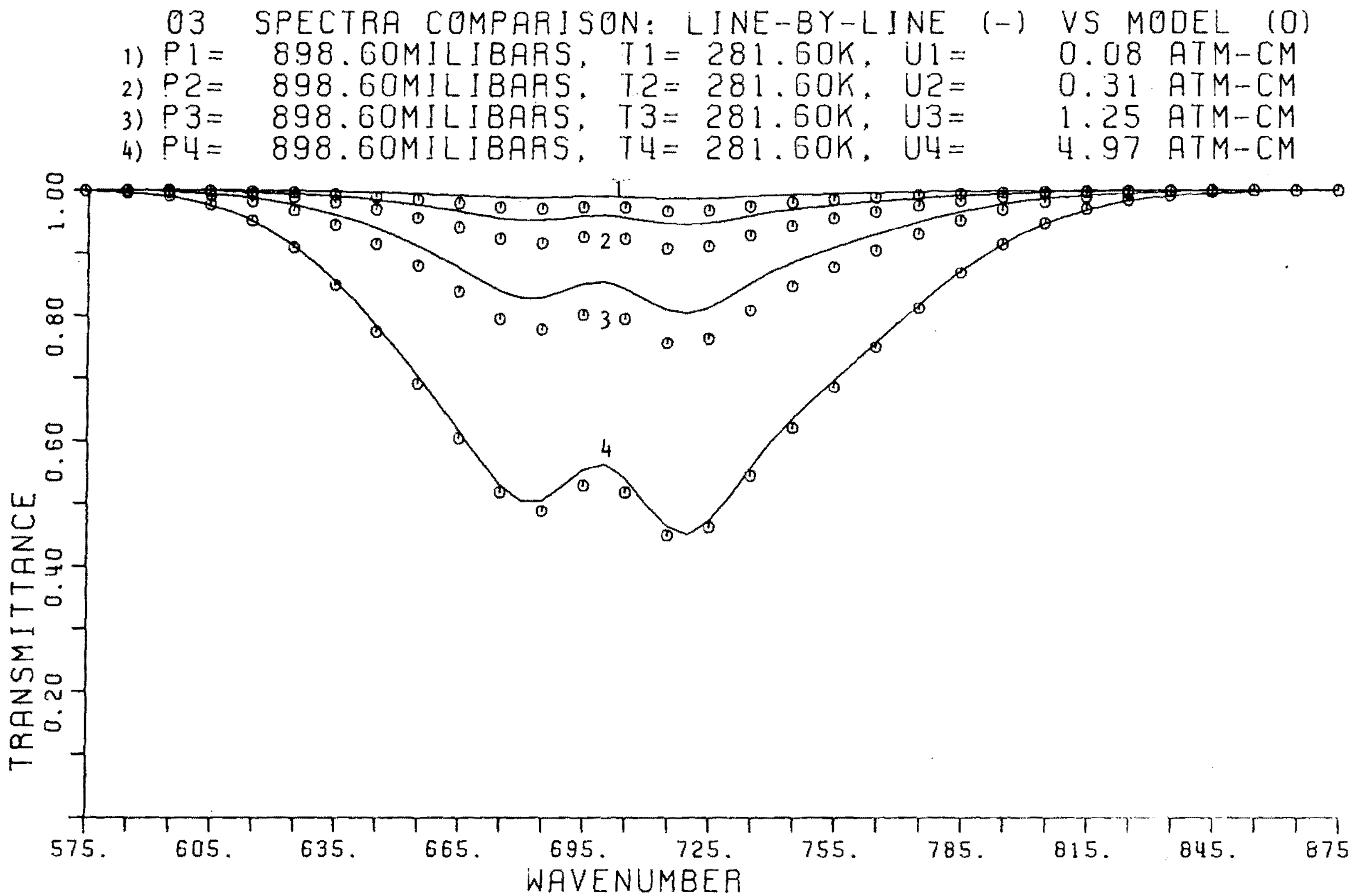

O3 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60MILIBARS, T1= 281.60K, U1= 0.08 ATM-CM
2) P2= 898.60MILIBARS, T2= 281.60K, U2= 0.31 ATM-CM
3) P3= 898.60MILIBARS, T3= 281.60K, U3= 1.25 ATM-CM
4) P4= 898.60MILIBARS, T4= 281.60K, U4= 4.97 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
WAVENUMBER
575.
605.
635.
665.
695.
725.
755.
785.
815.
845.
875.
1
2
3
4

Figure E15

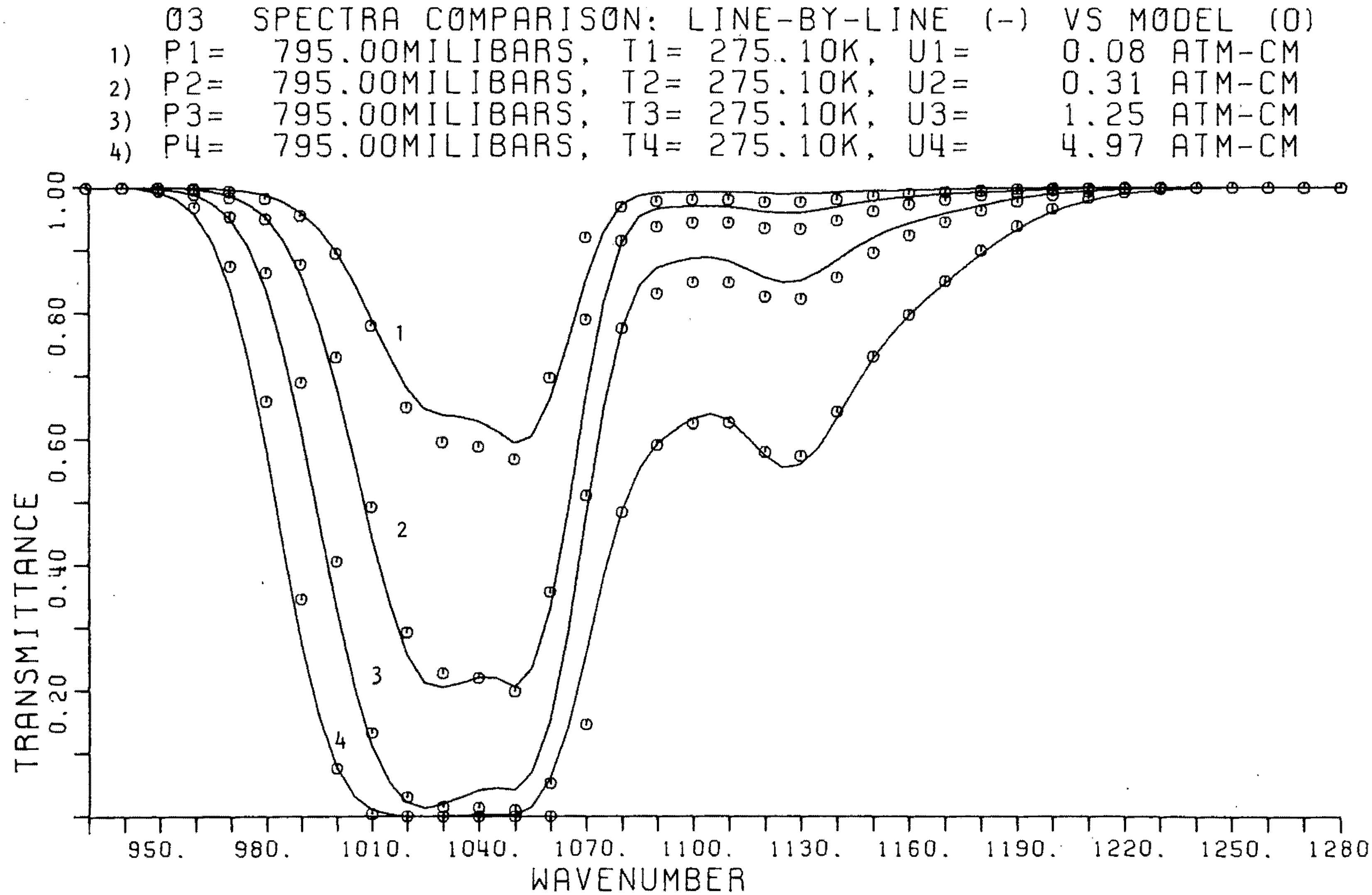

O3 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00MILIBARS, T1= 275.10K, U1= 0.08 ATM-CM
2) P2= 795.00MILIBARS, T2= 275.10K, U2= 0.31 ATM-CM
3) P3= 795.00MILIBARS, T3= 275.10K, U3= 1.25 ATM-CM
4) P4= 795.00MILIBARS, T4= 275.10K, U4= 4.97 ATM-CM
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
950.
980.
1010.
1040.
1070.
1100.
1130.
1160.
1190.
1220.
1250.
1280.
WAVENUMBER
1
2
3
4

Figure E16

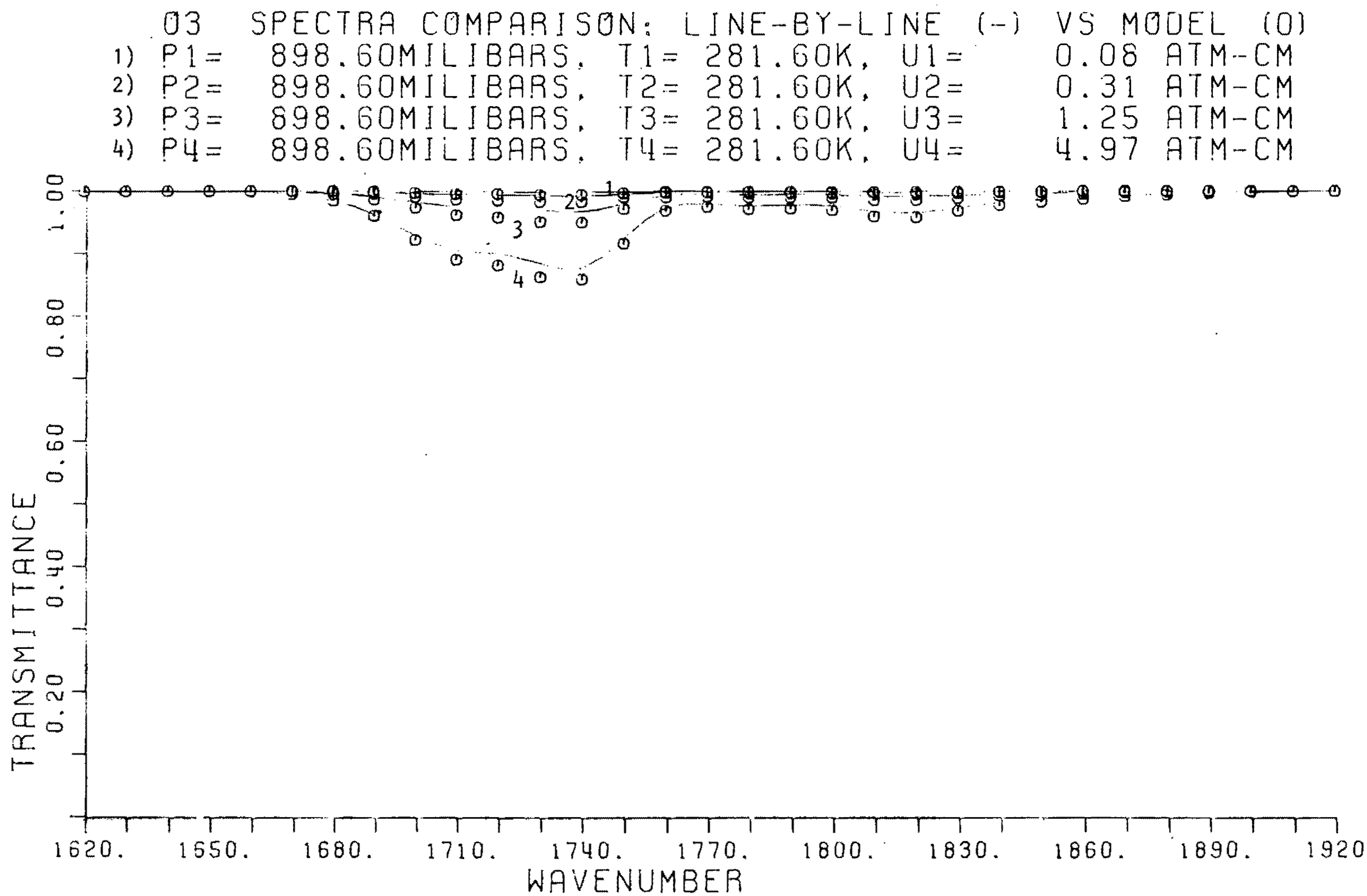

03 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60MILIBARS, T1= 281.60K, U1= 0.08 ATM-CM
2) P2= 898.60MILIBARS, T2= 281.60K, U2= 0.31 ATM-CM
3) P3= 898.60MILIBARS, T3= 281.60K, U3= 1.25 ATM-CM
4) P4= 898.60MILIBARS, T4= 281.60K, U4= 4.97 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1620.
1650.
1680.
1710.
1740.
1770.
1800.
1830.
1860.
1890.
1920.
WAVENUMBER

Figure E17

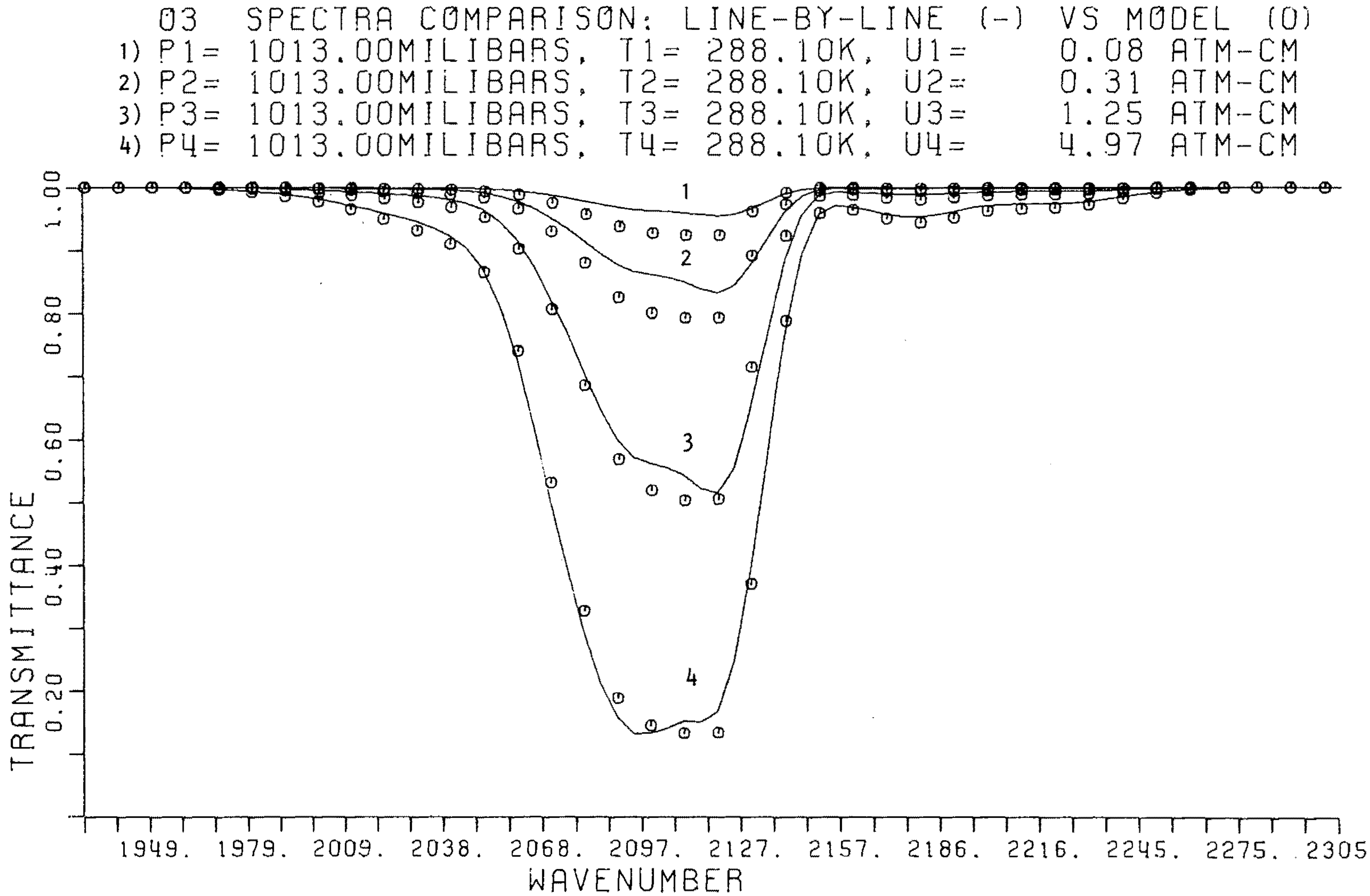

O3 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 1013.00MILIBARS, T1= 288.10K, U1= 0.08 ATM-CM
2) P2= 1013.00MILIBARS, T2= 288.10K, U2= 0.31 ATM-CM
3) P3= 1013.00MILIBARS, T3= 288.10K, U3= 1.25 ATM-CM
4) P4= 1013.00MILIBARS, T4= 288.10K, U4= 4.97 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
1949. 1979. 2009. 2038. 2068. 2097. 2127. 2157. 2186. 2216. 2245. 2275. 2305.
WAVENUMBER

Figure E18

APPENDIX F

Comparison Between Degraded Line-By-Line and Proposed Model Calculated Transmittance in the Spectral Region From 0 to 350 cm^{-1} for NH_3, CO, N_2O, O_2, O_3, SO_2, and H_2O.

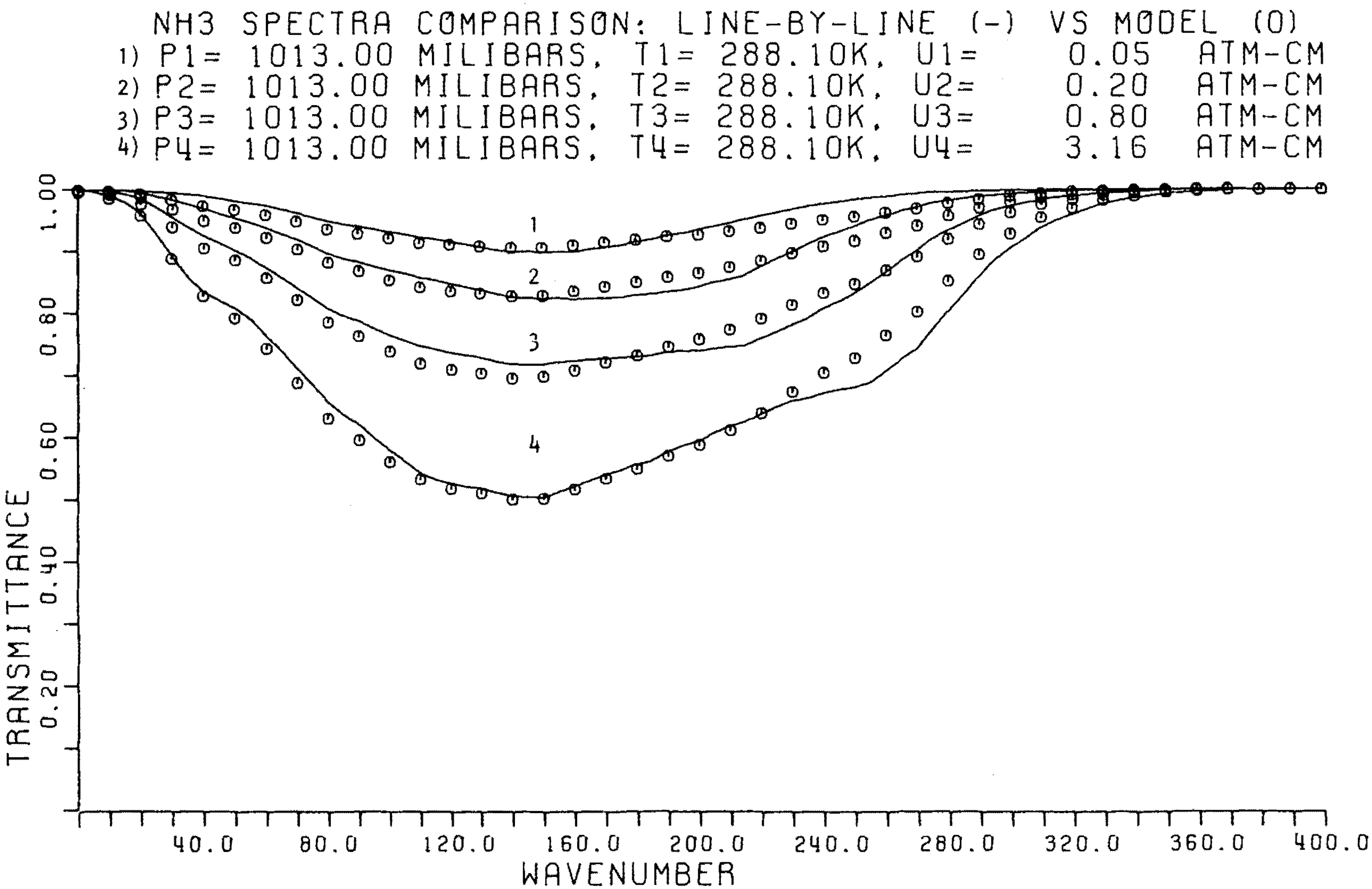

NH3 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 1013.00 MILIBARS, T1= 288.10K, U1= 0.05 ATM-CM
2) P2= 1013.00 MILIBARS, T2= 288.10K, U2= 0.20 ATM-CM
3) P3= 1013.00 MILIBARS, T3= 288.10K, U3= 0.80 ATM-CM
4) P4= 1013.00 MILIBARS, T4= 288.10K, U4= 3.16 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
WAVENUMBER

Figure F1

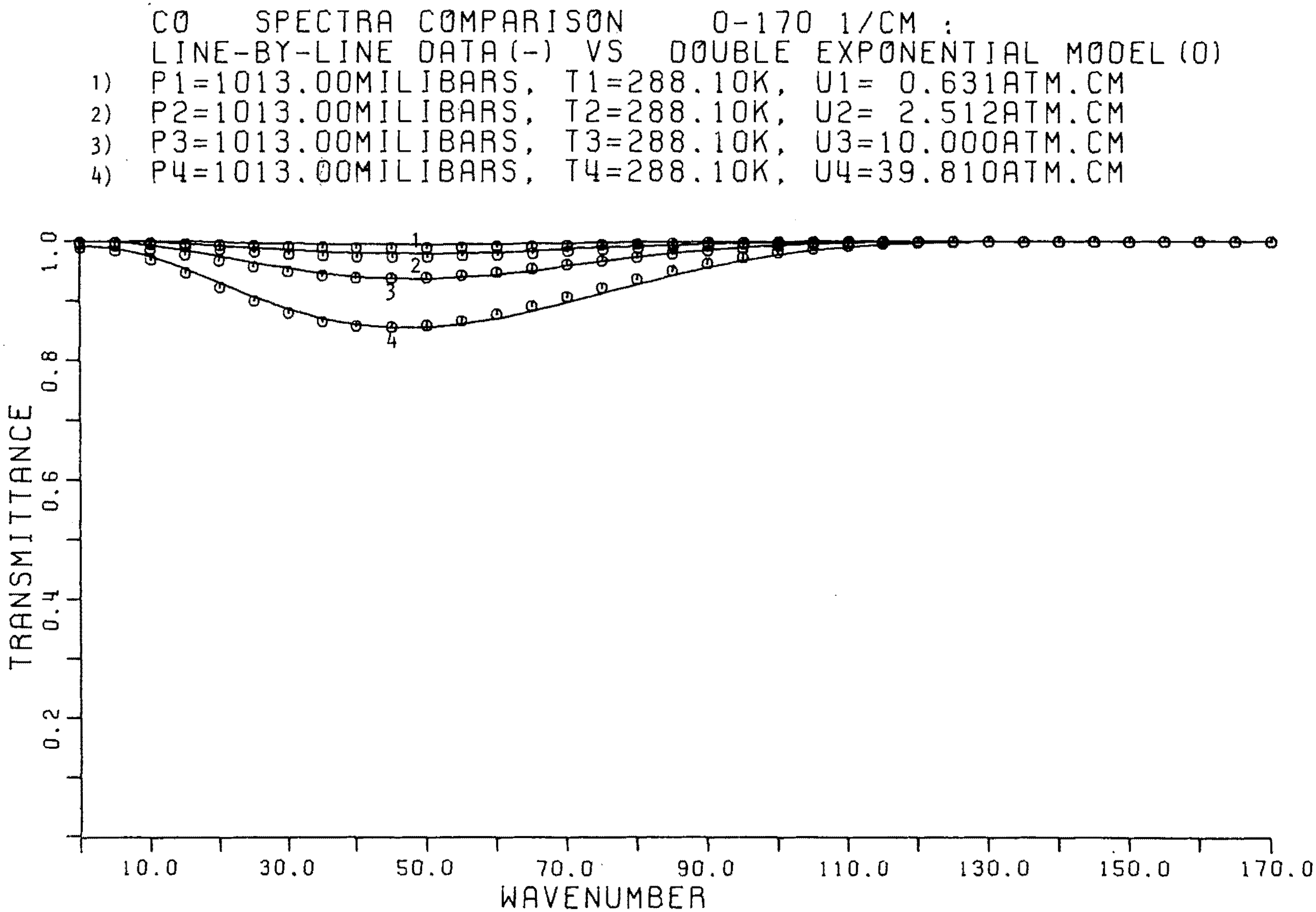

CO SPECTRA COMPARISON 0-170 1/CM :
LINE-BY-LINE DATA(-) VS DOUBLE EXPONENTIAL MODEL(O)
1) P1=1013.00MILIBARS, T1=288.10K, U1= 0.631ATM.CM
2) P2=1013.00MILIBARS, T2=288.10K, U2= 2.512ATM.CM
3) P3=1013.00MILIBARS, T3=288.10K, U3=10.000ATM.CM
4) P4=1013.00MILIBARS, T4=288.10K, U4=39.810ATM.CM
TRANSMITTANCE
1.0
0.8
0.6
0.4
0.2
1
2
3
4
10.0
30.0
50.0
70.0
90.0
110.0
130.0
150.0
170.0
WAVENUMBER

Figure F2

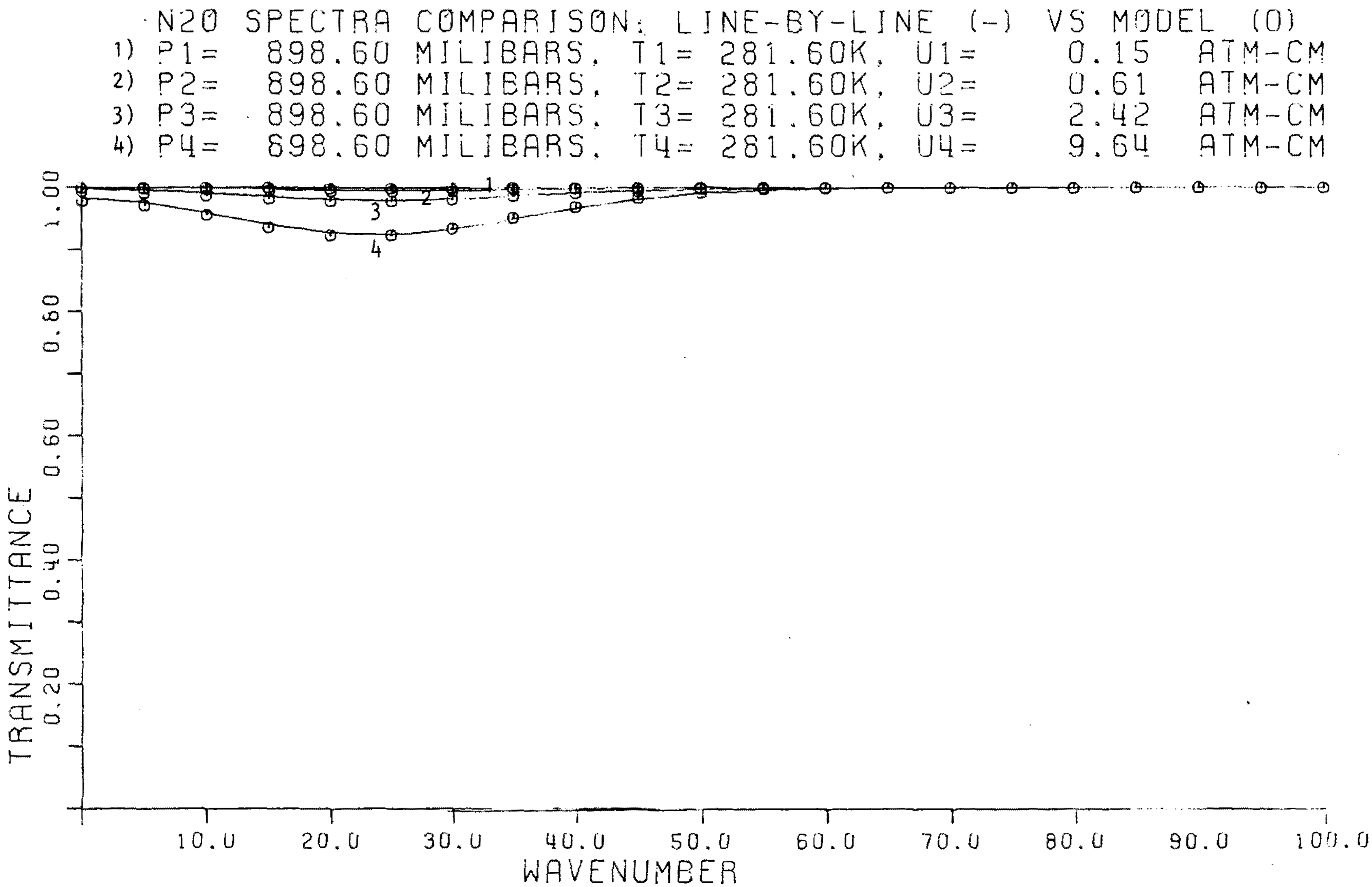

N2O SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 898.60 MILIBARS, T1= 281.60K, U1= 0.15 ATM-CM
2) P2= 898.60 MILIBARS, T2= 281.60K, U2= 0.61 ATM-CM
3) P3= 898.60 MILIBARS, T3= 281.60K, U3= 2.42 ATM-CM
4) P4= 898.60 MILIBARS, T4= 281.60K, U4= 9.64 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1
2
3
4
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
WAVENUMBER

Figure F3

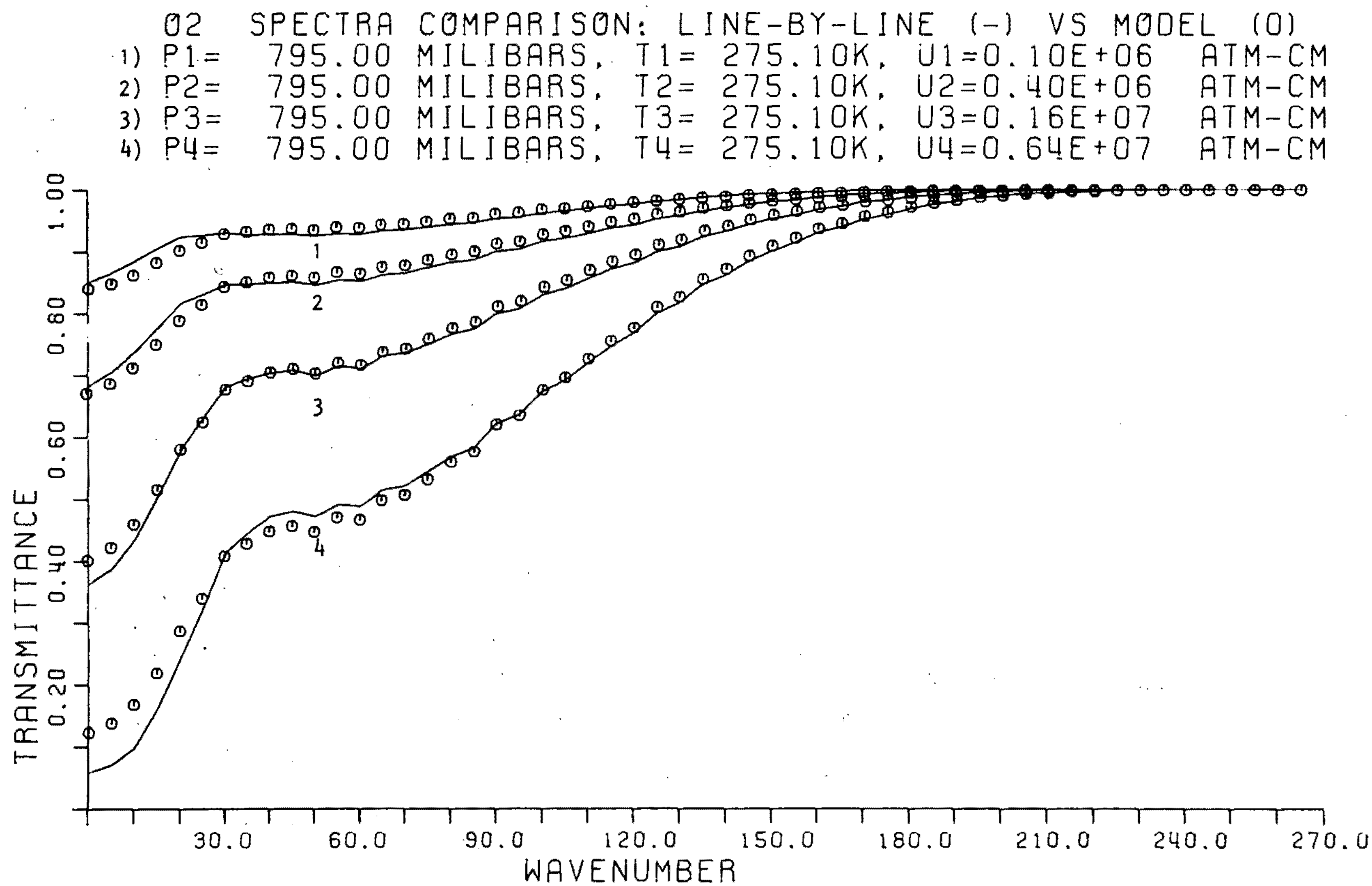

O2 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00 MILIBARS, T1= 275.10K, U1=0.10E+06 ATM-CM
2) P2= 795.00 MILIBARS, T2= 275.10K, U2=0.40E+06 ATM-CM
3) P3= 795.00 MILIBARS, T3= 275.10K, U3=0.16E+07 ATM-CM
4) P4= 795.00 MILIBARS, T4= 275.10K, U4=0.64E+07 ATM-CM
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
1
2
3
4
30.0
60.0
90.0
120.0
150.0
180.0
210.0
240.0
270.0
WAVENUMBER

Figure F4

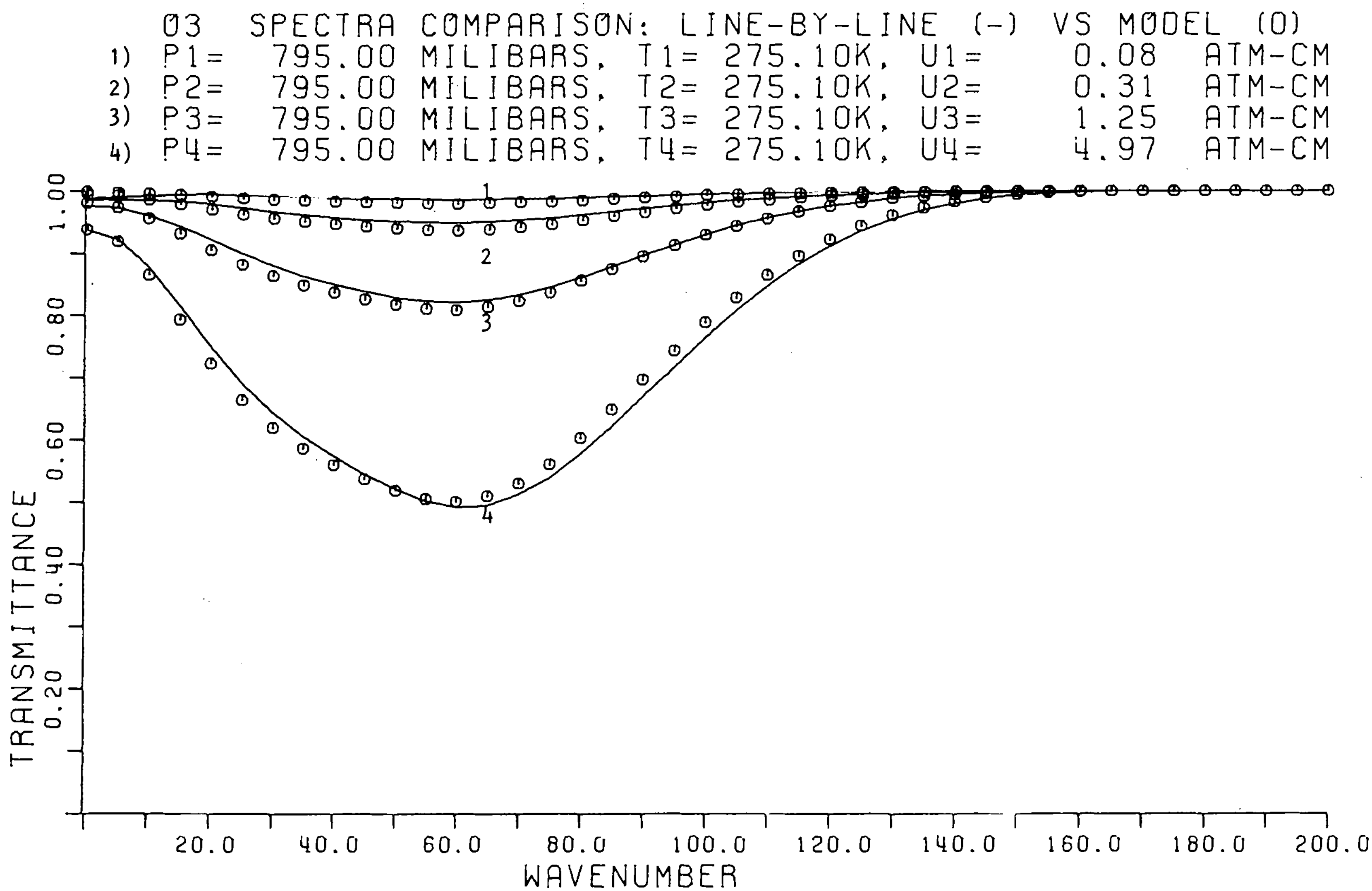

O3 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00 MILIBARS, T1= 275.10K, U1= 0.08 ATM-CM
2) P2= 795.00 MILIBARS, T2= 275.10K, U2= 0.31 ATM-CM
3) P3= 795.00 MILIBARS, T3= 275.10K, U3= 1.25 ATM-CM
4) P4= 795.00 MILIBARS, T4= 275.10K, U4= 4.97 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
WAVENUMBER
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
1
2
3
4

Figure F5

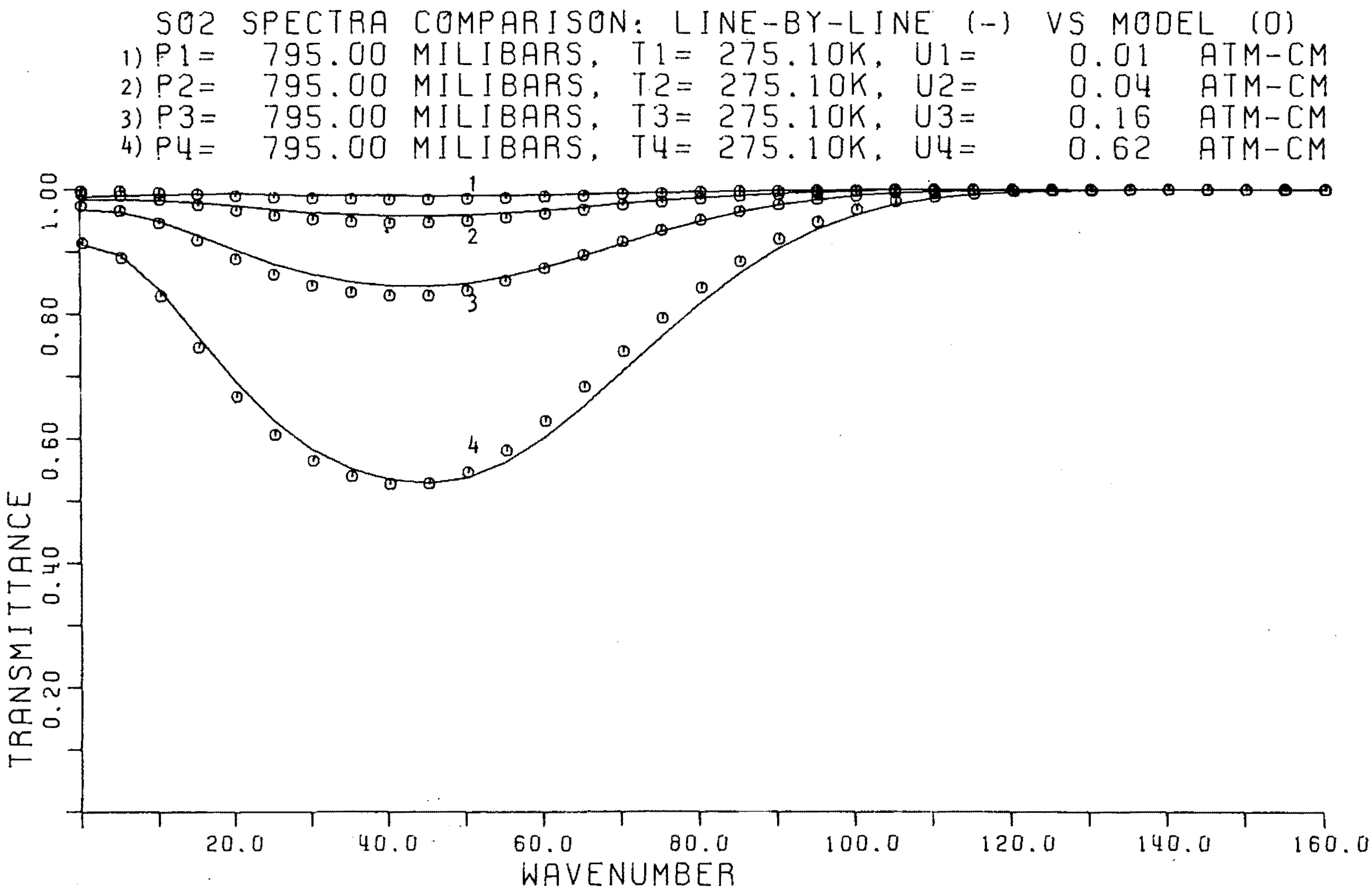

SO2 SPECTRA COMPARISON: LINE-BY-LINE (-) VS MODEL (O)
1) P1= 795.00 MILIBARS, T1= 275.10K, U1= 0.01 ATM-CM
2) P2= 795.00 MILIBARS, T2= 275.10K, U2= 0.04 ATM-CM
3) P3= 795.00 MILIBARS, T3= 275.10K, U3= 0.16 ATM-CM
4) P4= 795.00 MILIBARS, T4= 275.10K, U4= 0.62 ATM-CM
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
WAVENUMBER
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
1
2
3
4

Figure F6

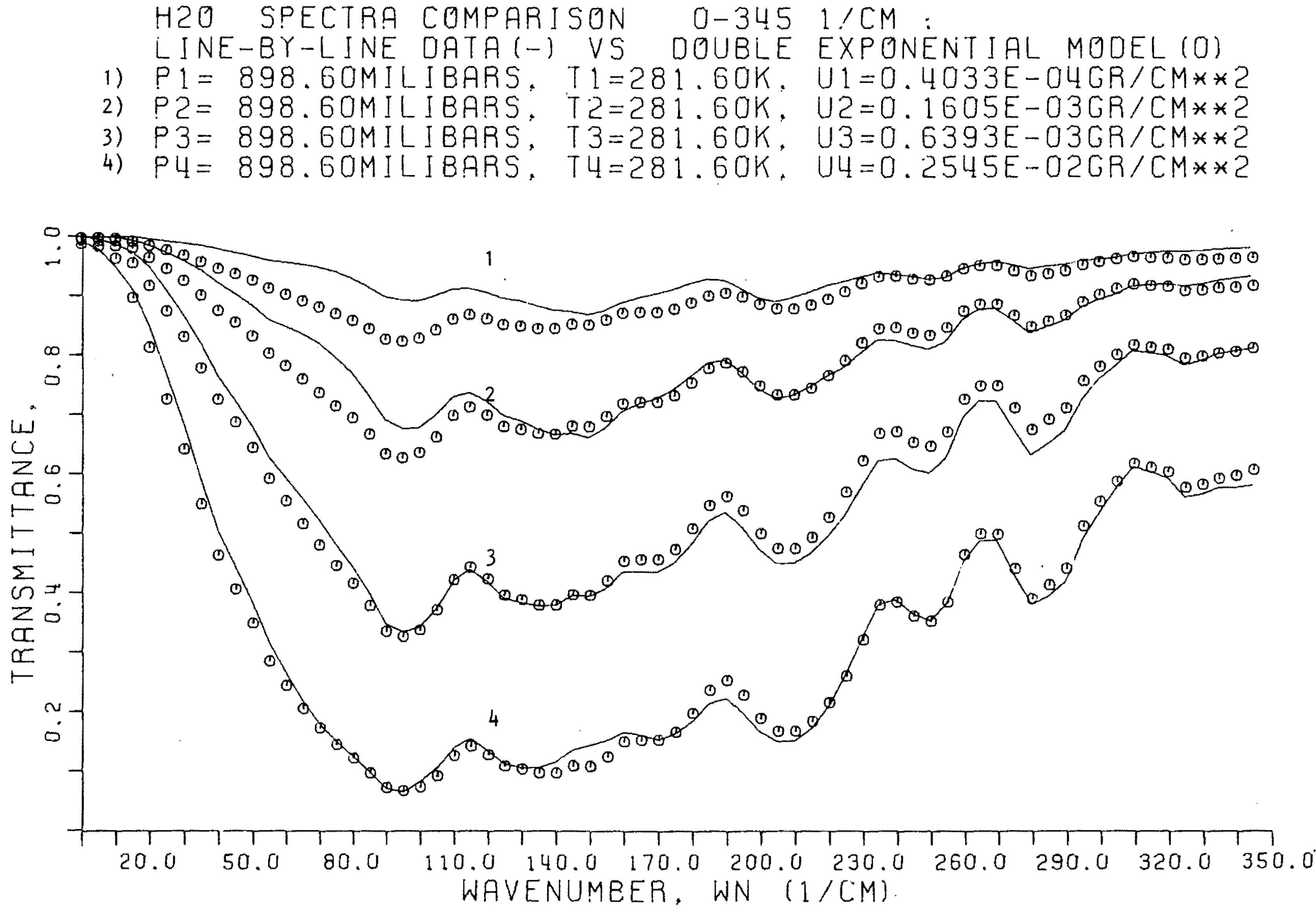

H2O SPECTRA COMPARISON 0-345 1/CM :
LINE-BY-LINE DATA(-) VS DOUBLE EXPONENTIAL MODEL(O)
1) P1= 898.60MILIBARS, T1=281.60K, U1=0.4033E-04GR/CM**2
2) P2= 898.60MILIBARS, T2=281.60K, U2=0.1605E-03GR/CM**2
3) P3= 898.60MILIBARS, T3=281.60K, U3=0.6393E-03GR/CM**2
4) P4= 898.60MILIBARS, T4=281.60K, U4=0.2545E-02GR/CM**2
TRANSMITTANCE,
1.0
0.8
0.6
0.4
0.2
1
2
3
4
20.0
50.0
80.0
110.0
140.0
170.0
200.0
230.0
260.0
290.0
320.0
350.0
WAVENUMBER, WN (1/CM)

Figure F7

APPENDIX G

Comparison Between LOWTRAN and Proposed Model Transmittance Calculations for the Uniformly Mixed Gases (N_2O, CH_4, CO, O_2, and CO_2 combined), H_2O and O_3.

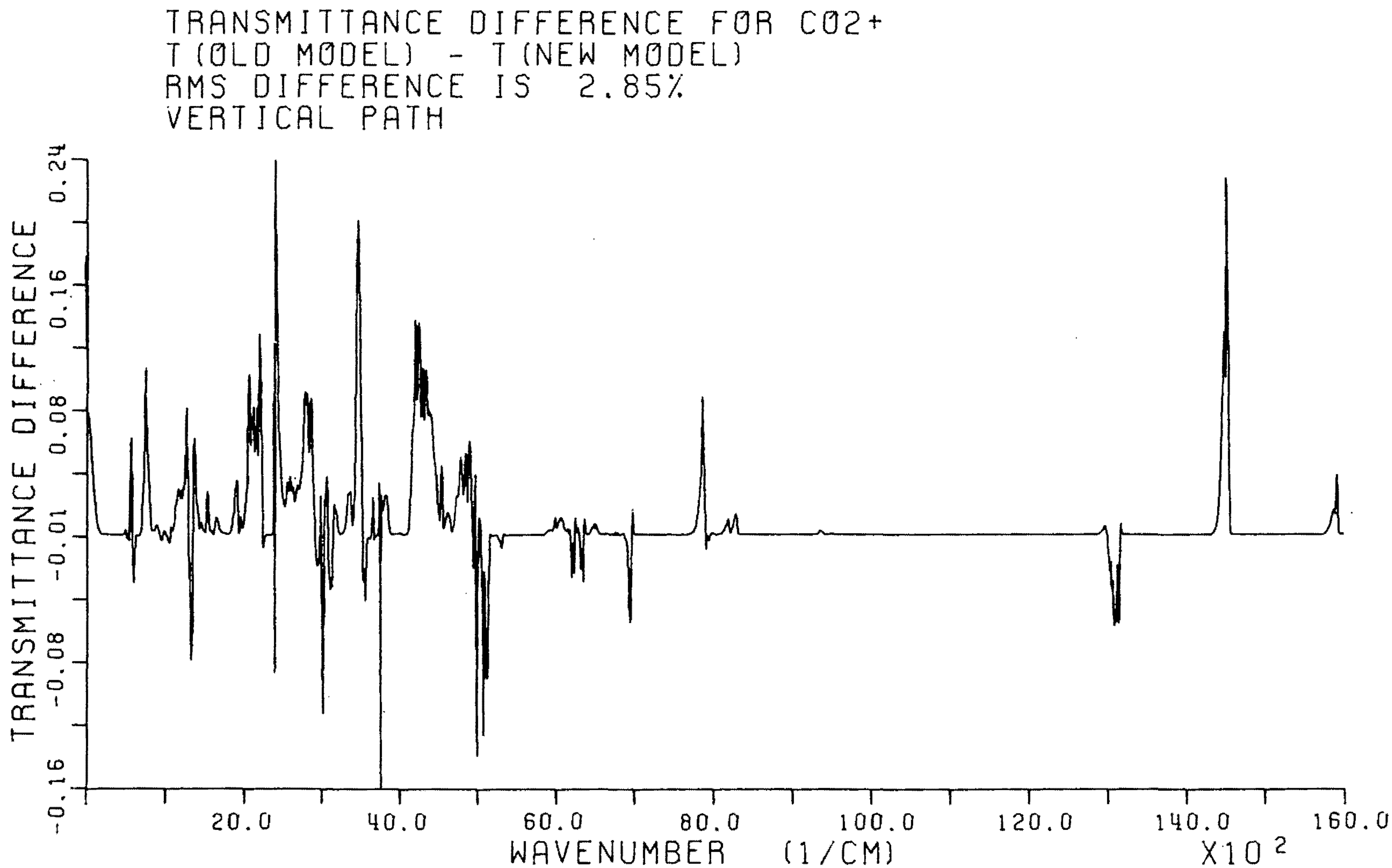

TRANSMITTANCE DIFFERENCE FØR CØ2+
T(ØLD MØDEL) - T(NEW MØDEL)
RMS DIFFERENCE IS 2.85%
VERTICAL PATH
TRANSMITTANCE DIFFERENCE
0.24
0.16
0.08
-0.01
-0.08
-0.16
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
WAVENUMBER (1/CM)
X10 2

Figure G1

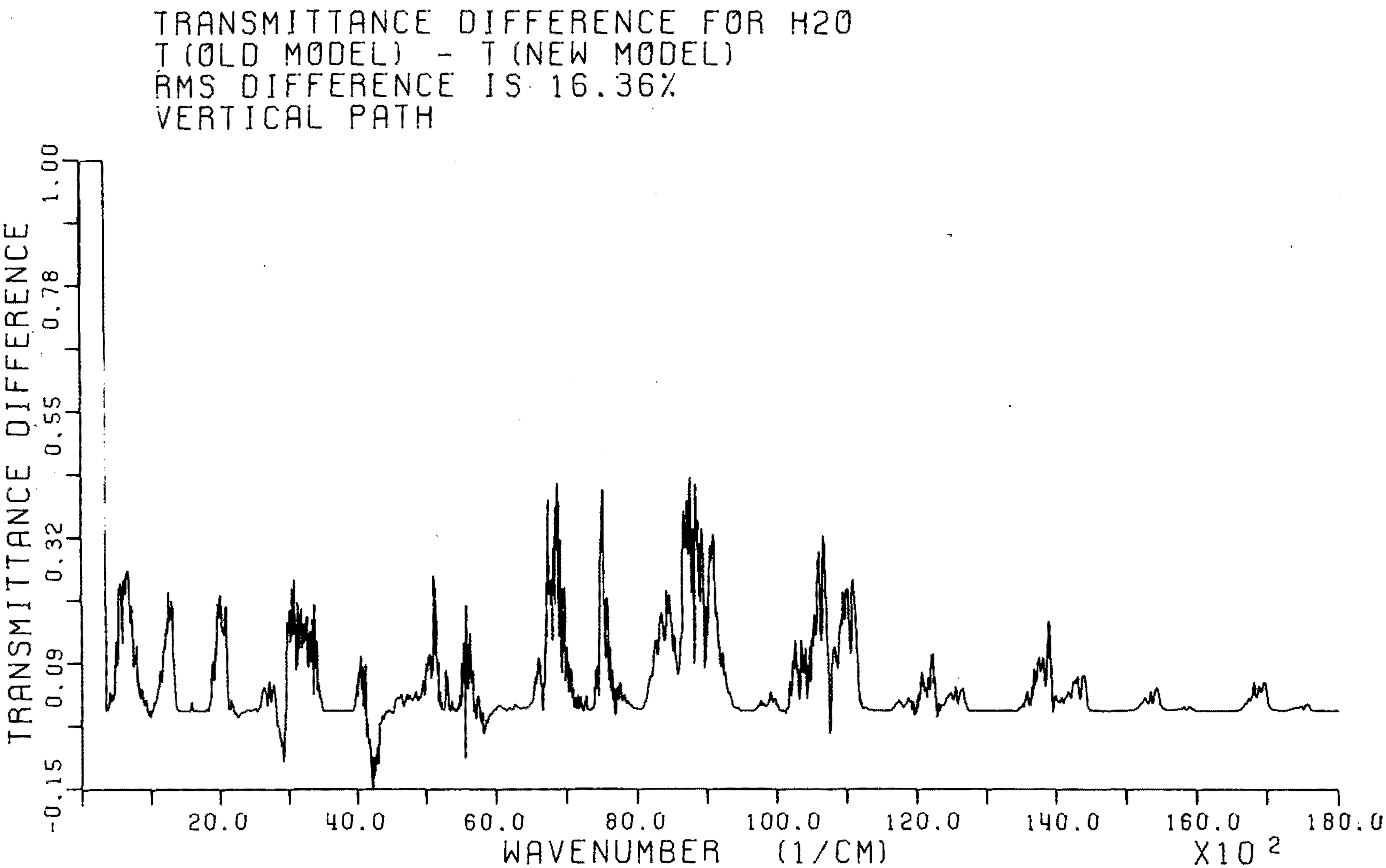

TRANSMITTANCE DIFFERENCE FOR H2O
T(OLD MODEL) - T(NEW MODEL)
RMS DIFFERENCE IS 16.36%
VERTICAL PATH
TRANSMITTANCE DIFFERENCE
1.00
0.78
0.55
0.32
0.09
-0.15
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
WAVENUMBER (1/CM)
X10 2

Figure G2

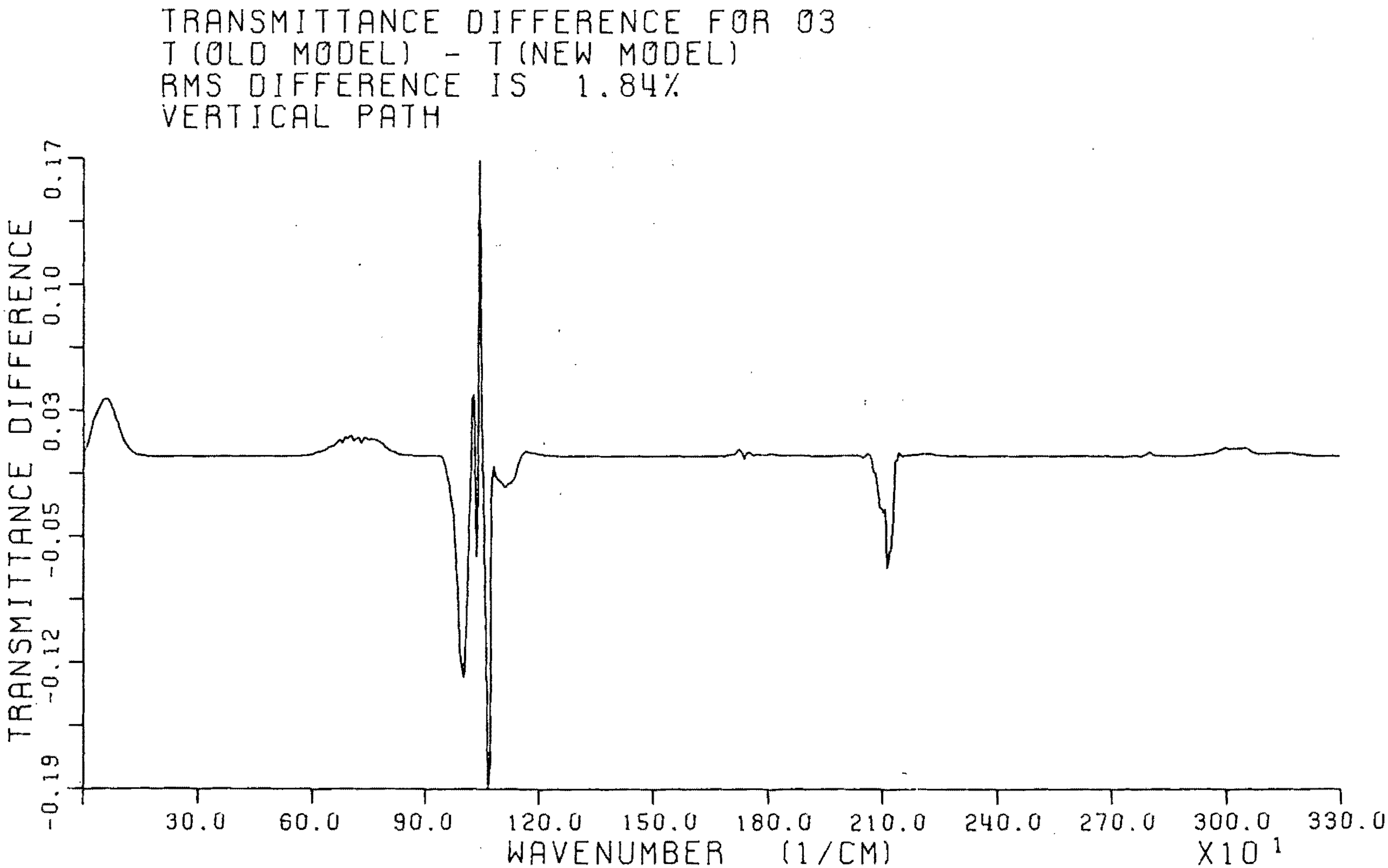

TRANSMITTANCE DIFFERENCE FOR O3
T(OLD MODEL) - T(NEW MODEL)
RMS DIFFERENCE IS 1.84%
VERTICAL PATH
TRANSMITTANCE DIFFERENCE
0.17
0.10
0.03
-0.05
-0.12
-0.19
30.0
60.0
90.0
120.0
150.0
180.0
210.0
240.0
270.0
300.0
330.0
WAVENUMBER (1/CM)
X10 1

Figure G3

APPENDIX H

Transmittance Through NH_3, CO_2, CO, CH_4, NO, NO_2, N_2O, O_2, O_3, SO_2 and H_2O in the U.S. Standard Atmosphere Along Atmospheric Paths Discussed in Texts.

The top curve represents transmittance through a vertical path, while the middle and bottom curves represent transmittances through a horizontal and tangent path, respectively.

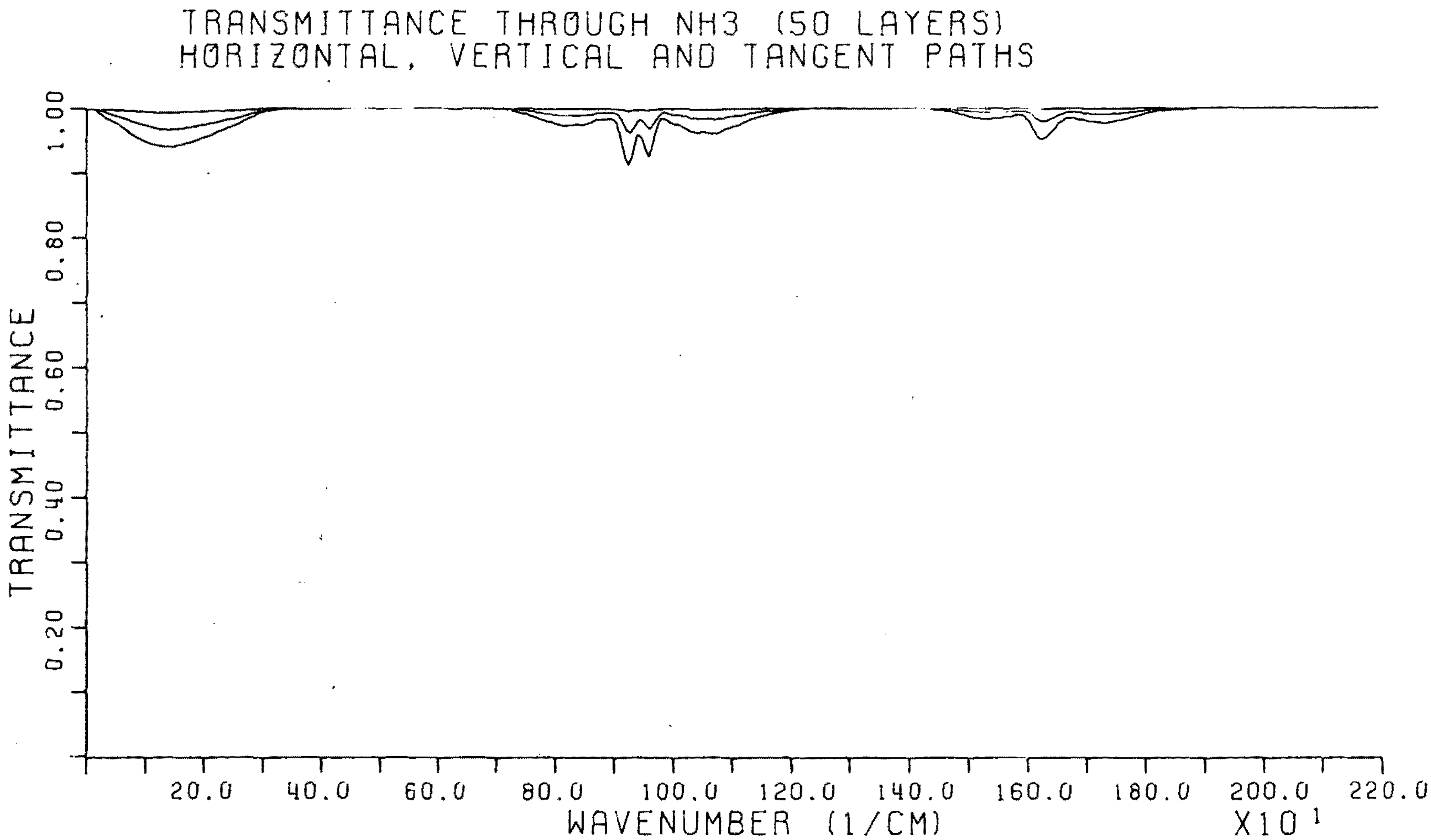
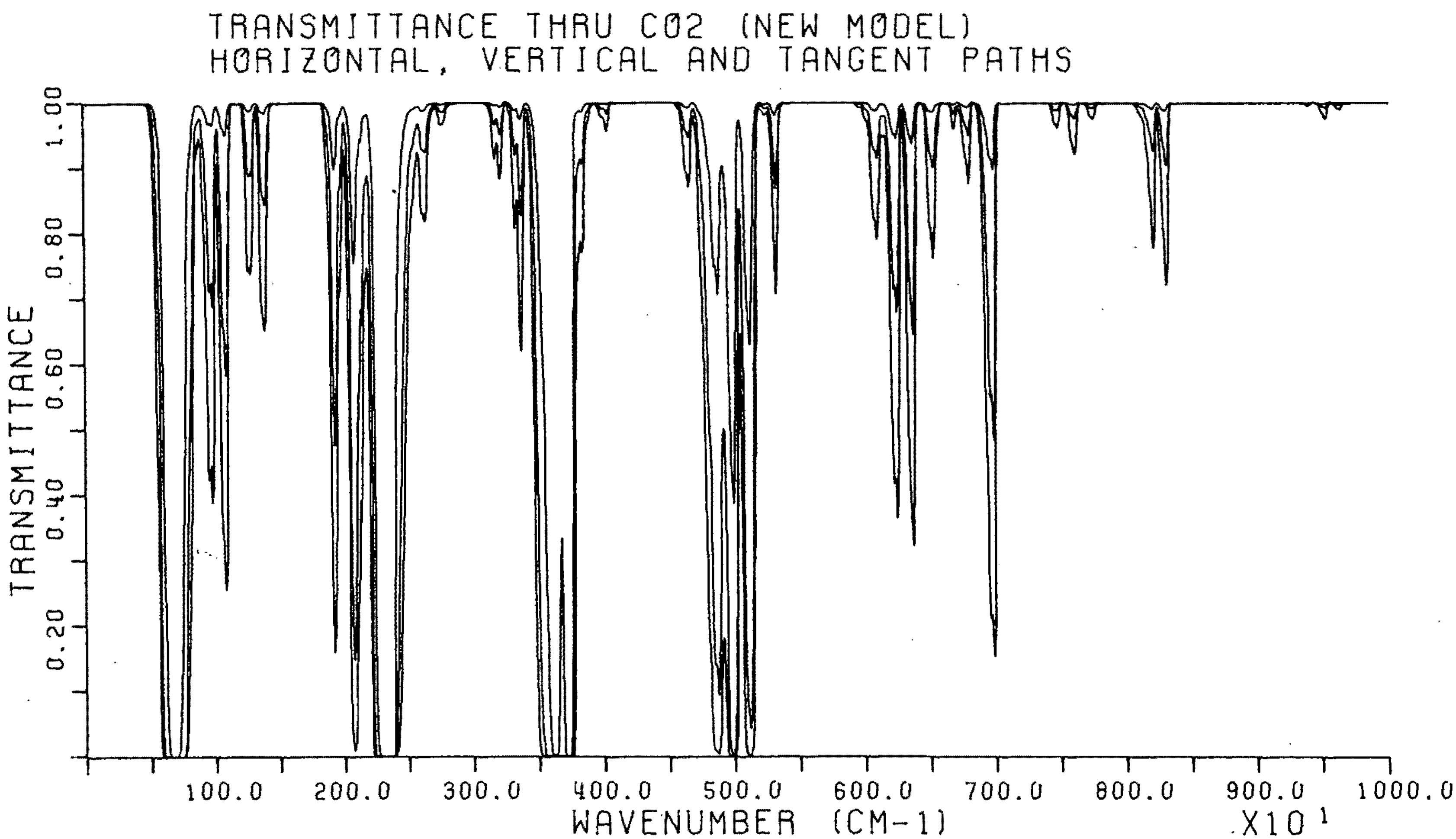

TRANSMITTANCE THROUGH NH3 (50 LAYERS)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
WAVENUMBER (1/CM)
X10 1

Figure H1



TRANSMITTANCE THRU CO2 (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
WAVENUMBER (CM-1)
X10 1

Figure H2

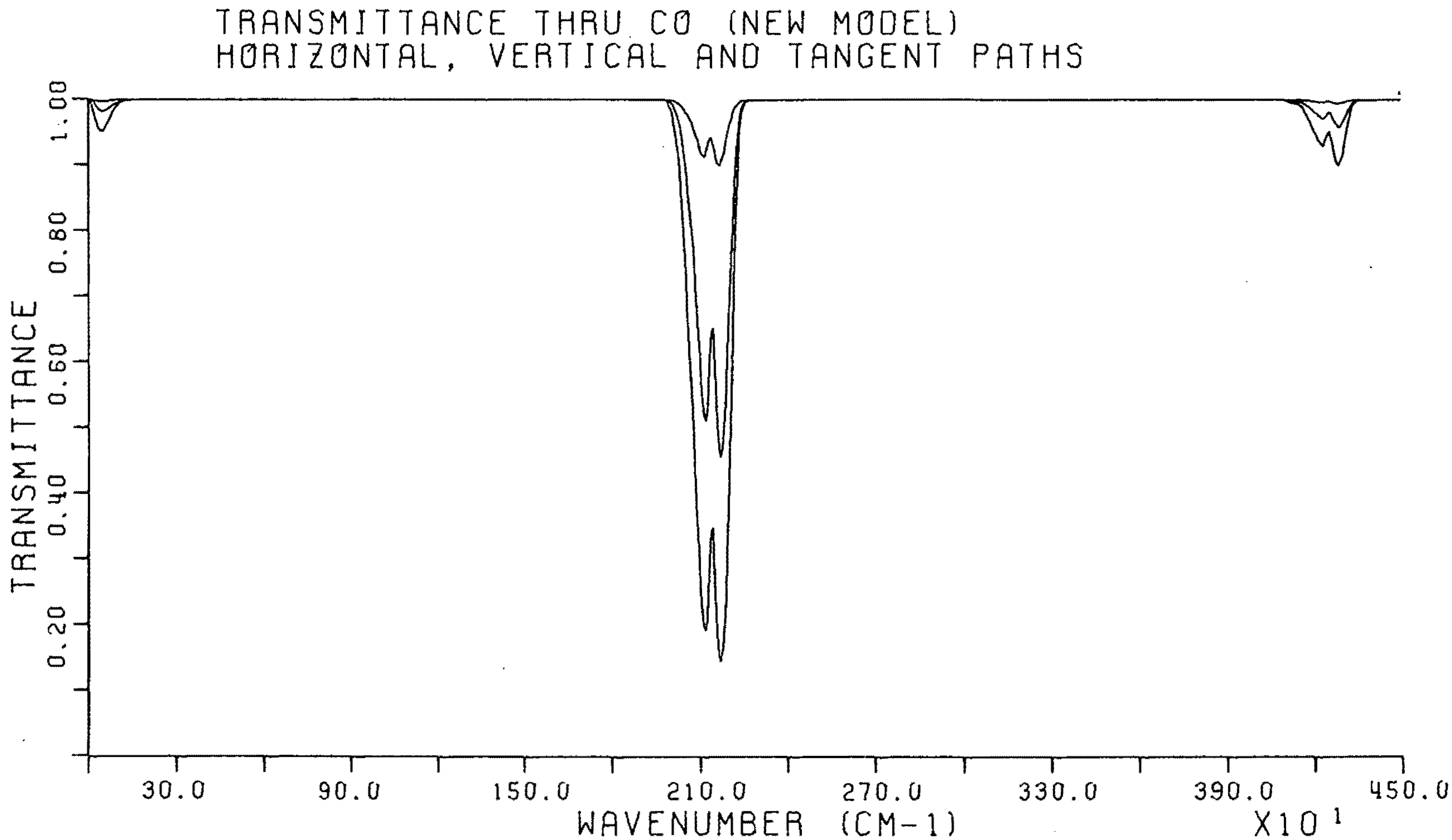

TRANSMITTANCE THRU CO (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
30.0
90.0
150.0
210.0
270.0
330.0
390.0
450.0
WAVENUMBER (CM-1)
X10 1

Figure H3

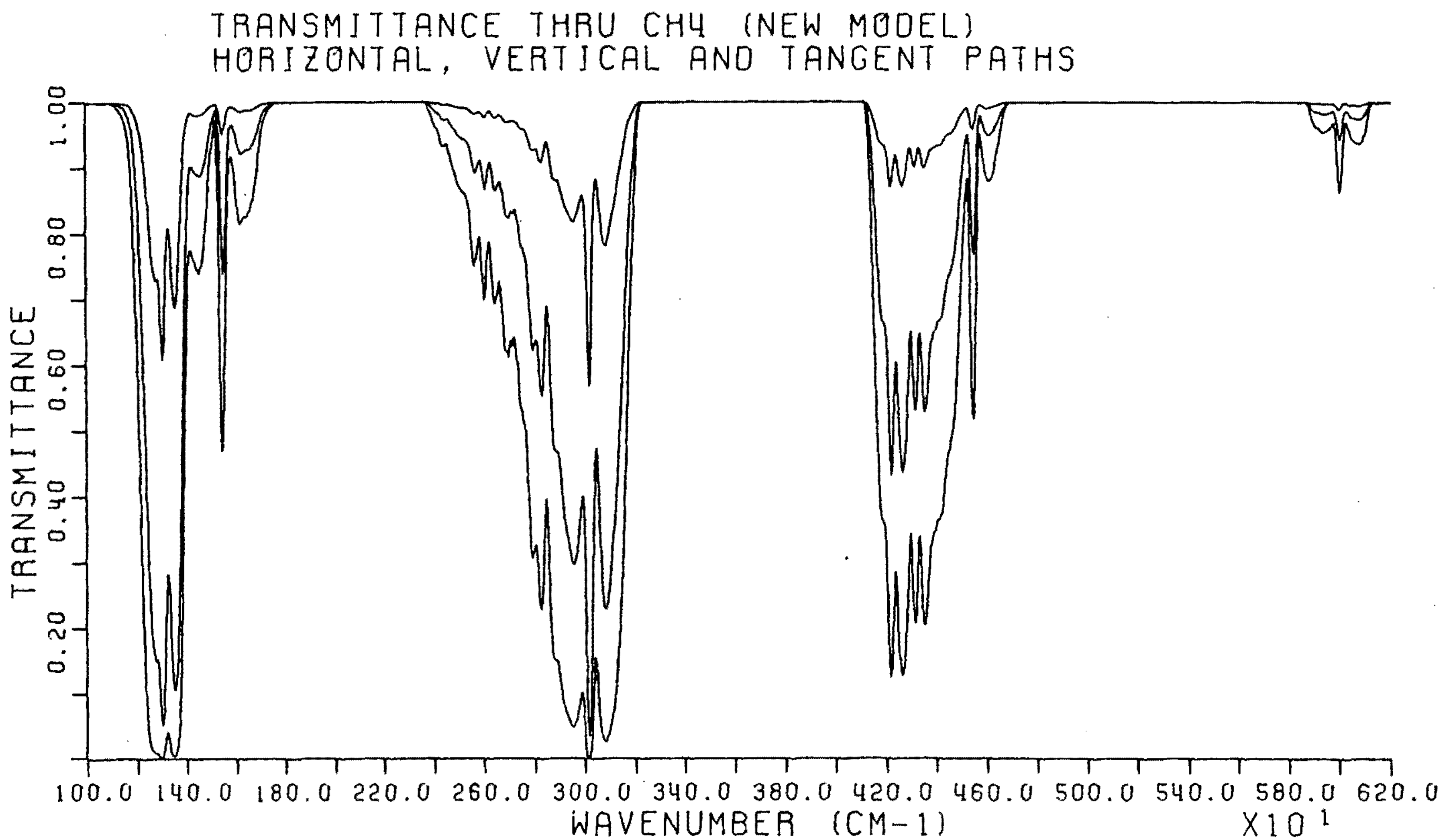

TRANSMITTANCE THRU CH4 (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
100.0 140.0 180.0 220.0 260.0 300.0 340.0 380.0 420.0 460.0 500.0 540.0 580.0 620.0
WAVENUMBER (CM-1)
X10 1

Figure H4

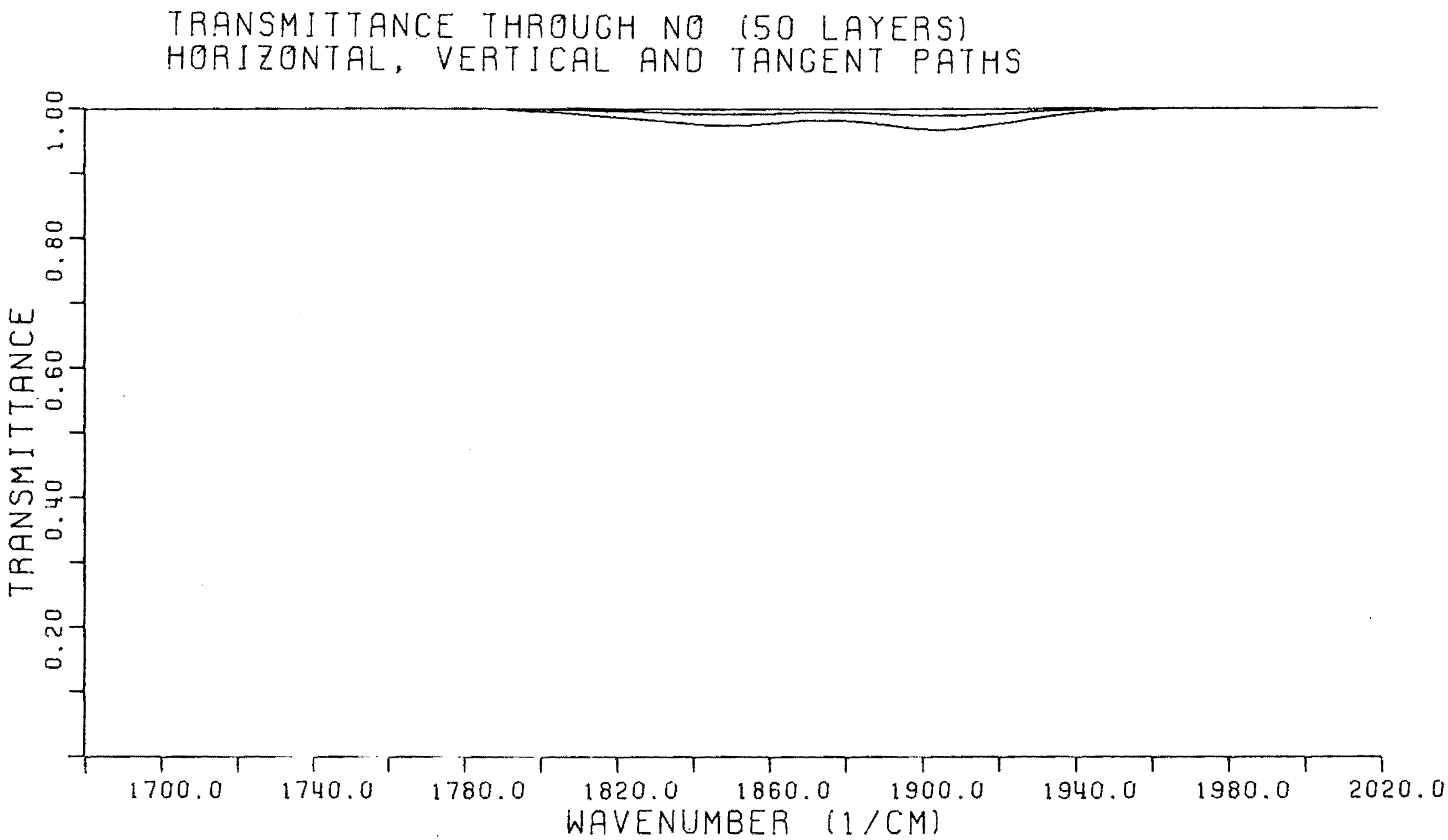

TRANSMITTANCE THROUGH NO (50 LAYERS)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
1700.0
1740.0
1780.0
1820.0
1860.0
1900.0
1940.0
1980.0
2020.0
WAVENUMBER (1/CM)

Figure H5

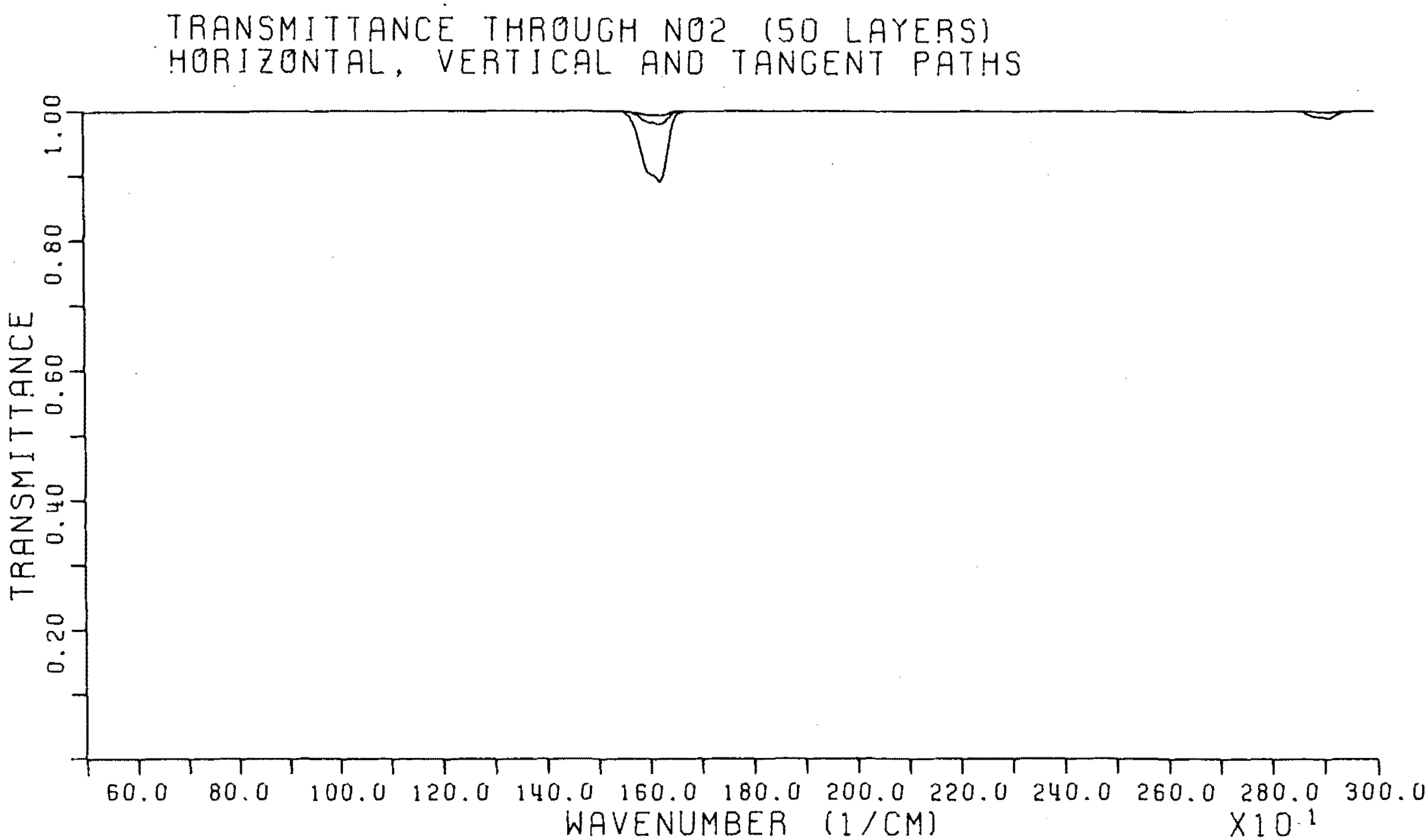

TRANSMITTANCE THROUGH NO2 (50 LAYERS)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
260.0
280.0
300.0
WAVENUMBER (1/CM)
X10 1

Figure H6

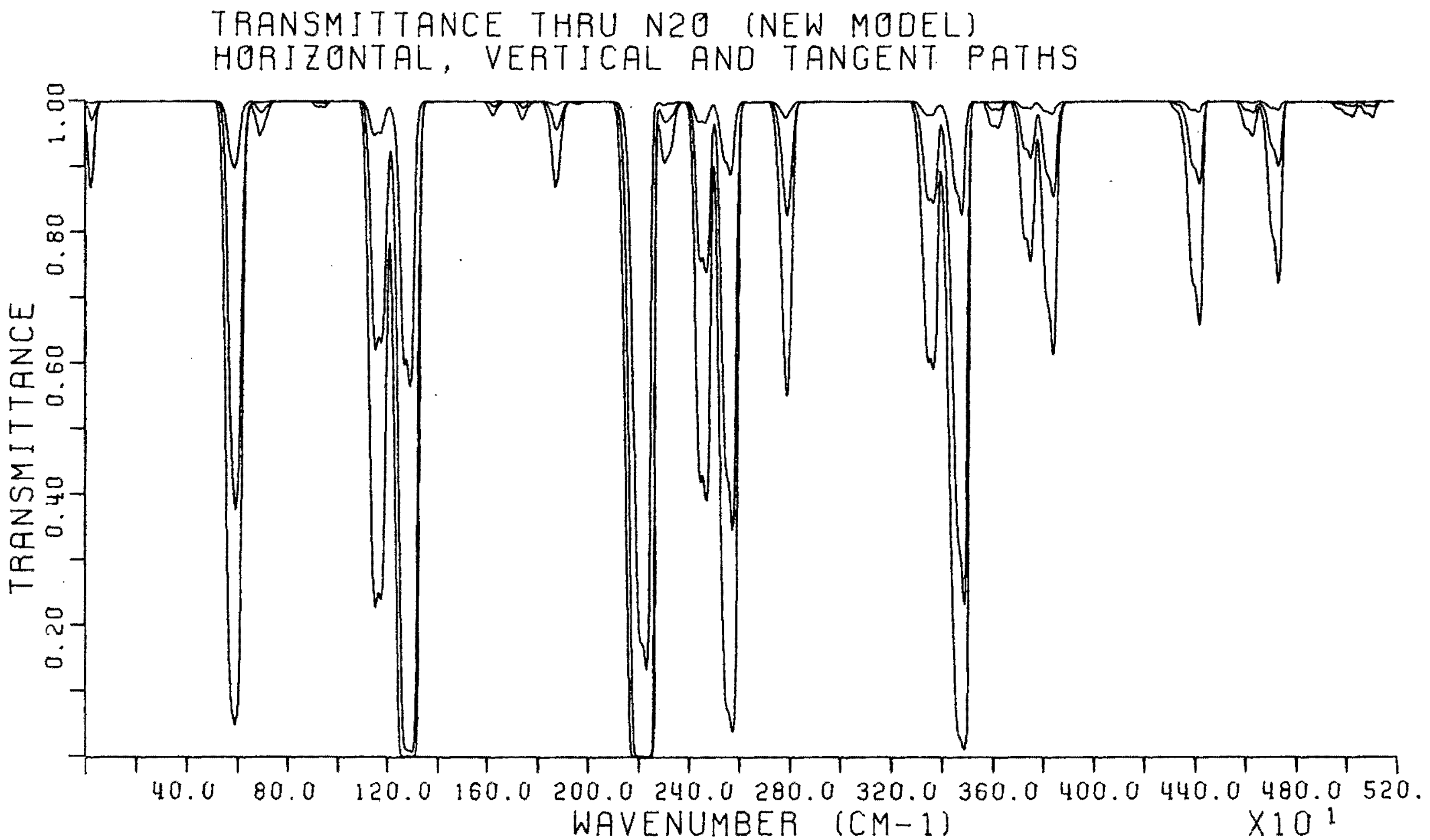

TRANSMITTANCE THRU N2O (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
440.0
480.0
520.0
WAVENUMBER (CM-1)
X10 1

Figure H7

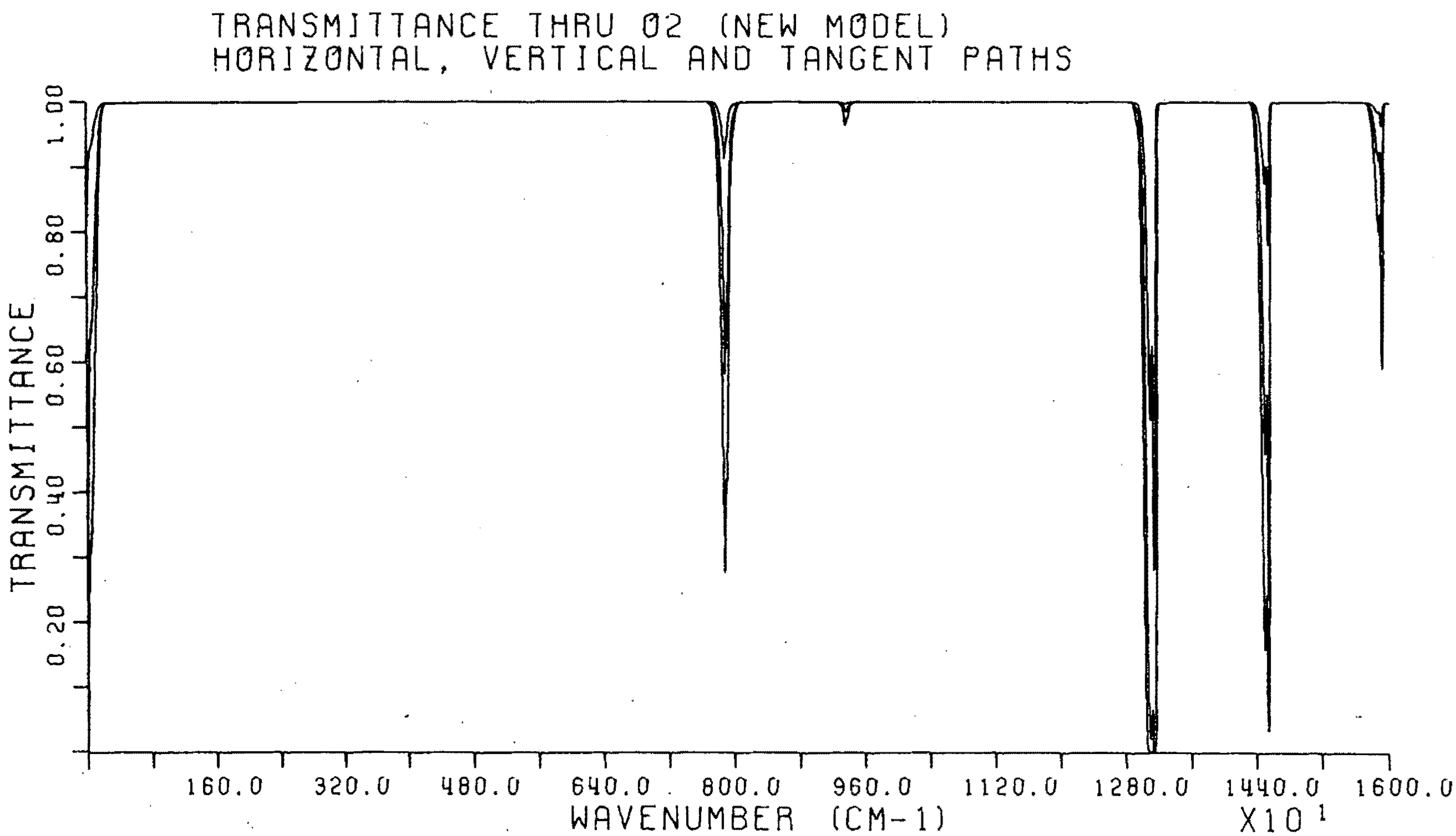

TRANSMITTANCE THRU O2 (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
160.0
320.0
480.0
640.0
800.0
960.0
1120.0
1280.0
1440.0
1600.0
WAVENUMBER (CM-1)
X10 1

Figure H8

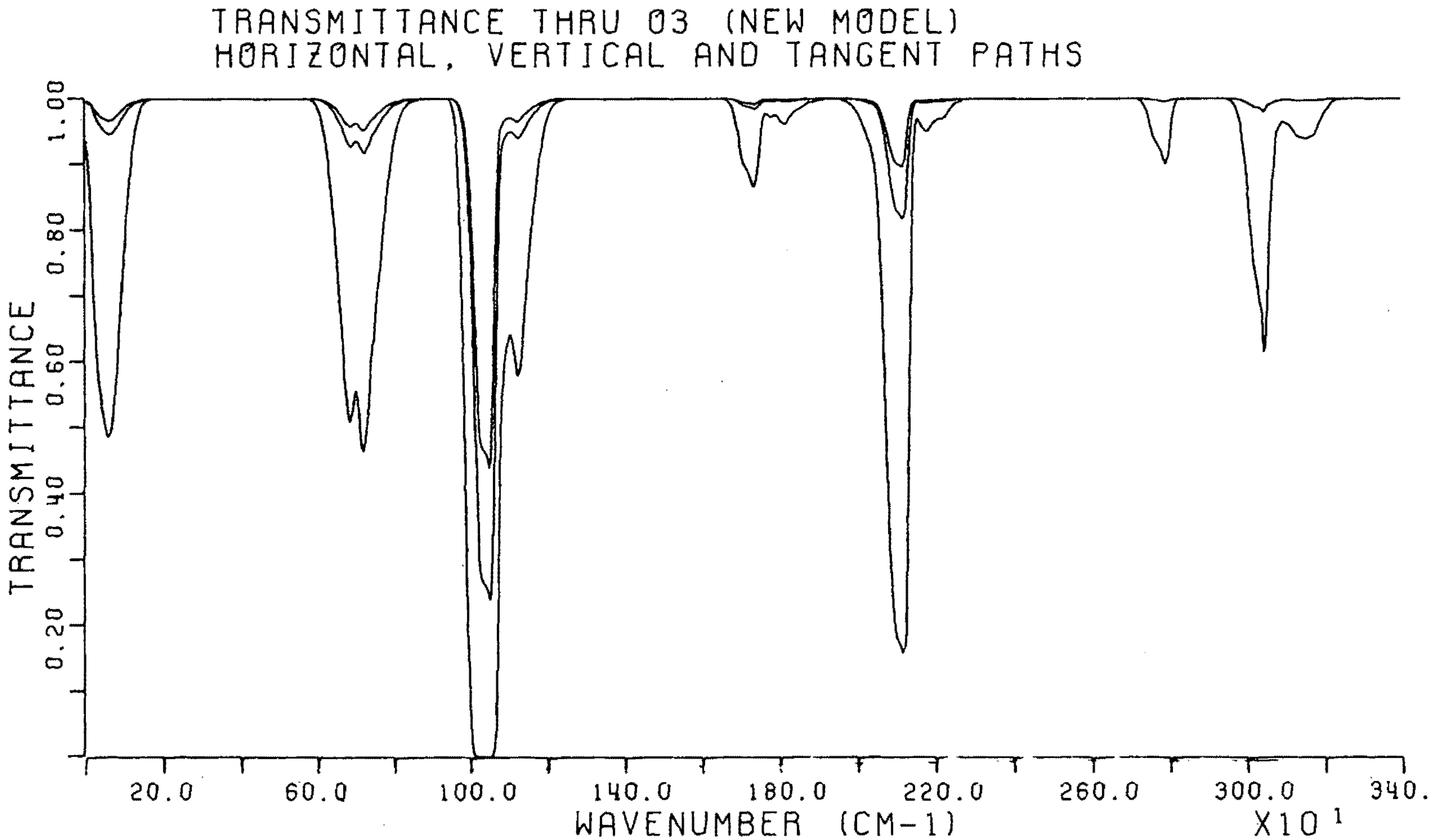

TRANSMITTANCE THRU O3 (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
20.0
60.0
100.0
140.0
180.0
220.0
260.0
300.0
340.0
WAVENUMBER (CM-1)
X10 1

Figure H9

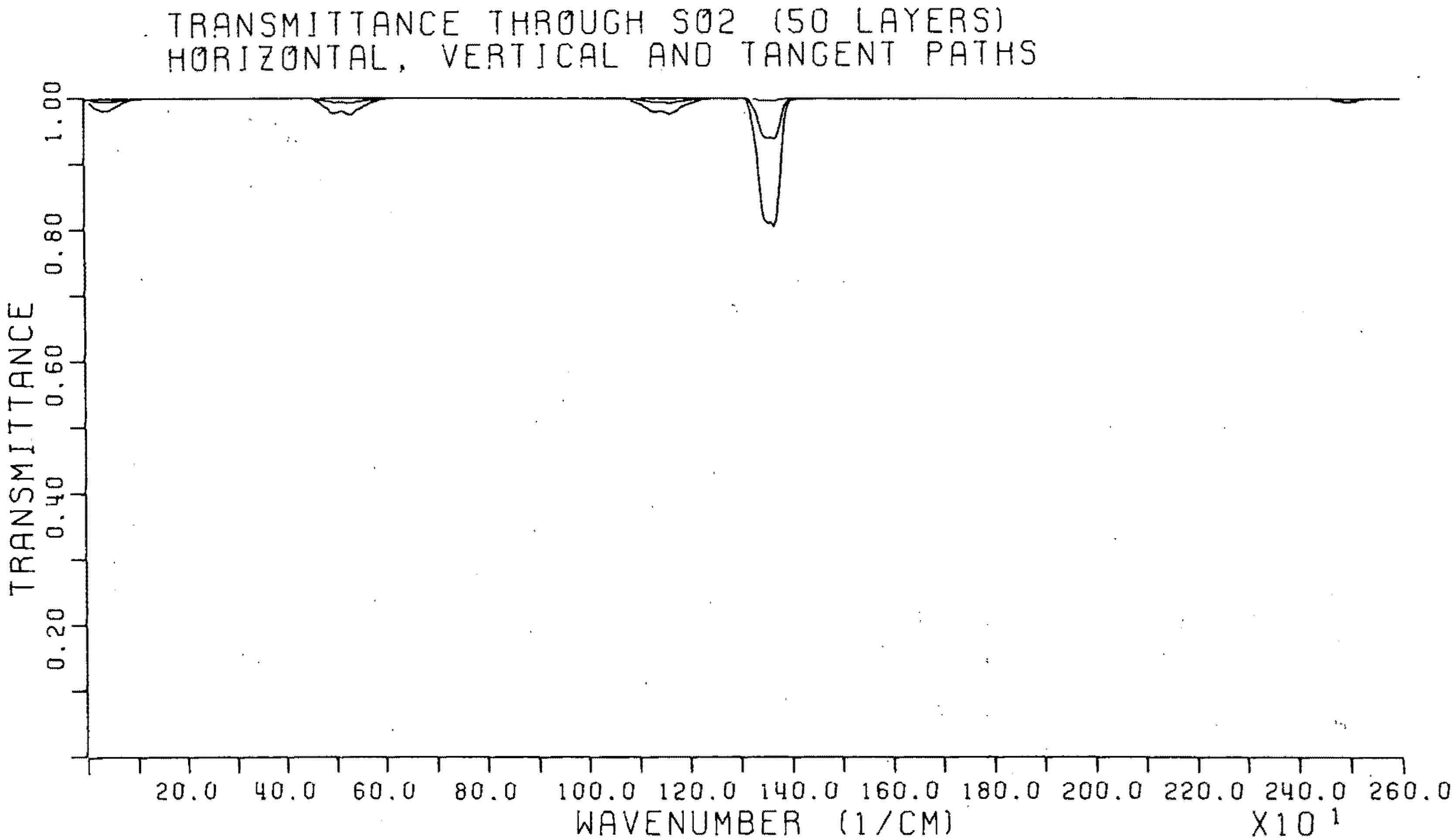

TRANSMITTANCE THROUGH S02 (50 LAYERS)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
1.00
0.80
0.60
0.40
0.20
20.0 40.0 60.0 80.0 100.0 120.0 140.0 160.0 180.0 200.0 220.0 240.0 260.0
WAVENUMBER (1/CM)
X10 1

Figure H10

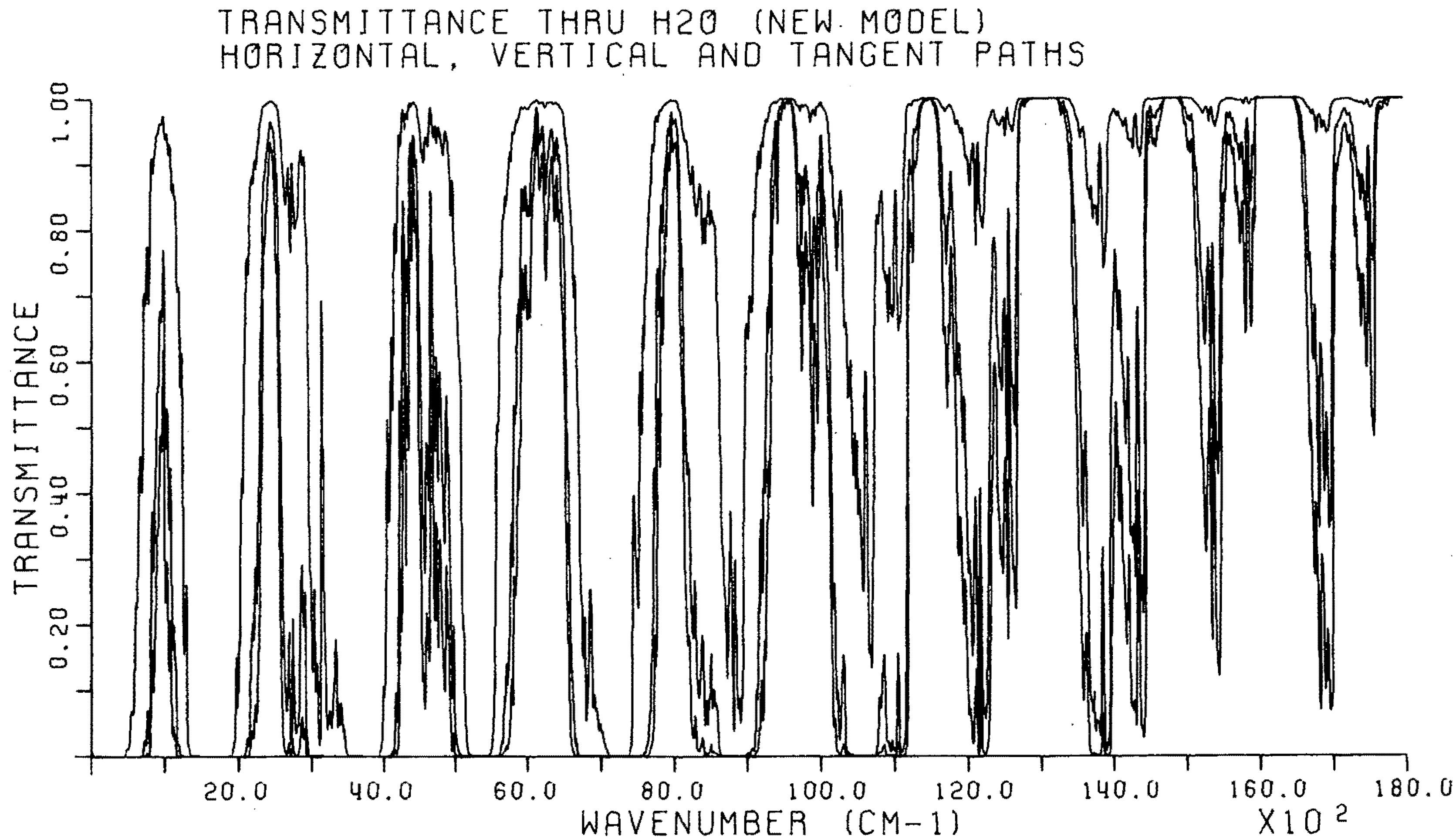

TRANSMITTANCE THRU H2O (NEW MODEL)
HORIZONTAL, VERTICAL AND TANGENT PATHS
TRANSMITTANCE
0.20
0.40
0.60
0.80
1.00
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
WAVENUMBER (CM-1)
X10 2

Figure H11

APPENDIX I

Papers published under this contractual effort.

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Validated band model for the NO fundamental

Joseph H. Pierluissi, Ken Tomiyama, and Francis X. Kneizys

A previously reported transmission model for the 5.3-μm band of NO, whose defining parameters had been developed with line-by-line calculated spectra, is now presented in validated and upgraded form through the use of measured transmittance data. The model consists of a double-exponential function, which approximates homogeneous-path transmittance at 5-cm^{-1} intervals with a sepctral resolution of 20 cm^{-1}. The use of the proposed model parameters in transmittance calculations yielded an average standard deviation of 0.28% and an overall maximum deviation of 1.48% from the measured transmittance data. This compares favorably with the results obtained with the use of the previous parameters to predict the measurements, which resulted in an average deviation of 1.05% and overall maximum transmittance deviation of 4.94%.

I. Introduction

Nitric oxide is an atmospheric trace gas constituent which reaches typical concentration of ~0.50 ppbv,[1] attaining much higher values in polluted environments. The intensity of its fundamental absorption band centered at 5.3 μm has been thoroughly studied by at least fifteen independent laboratories.[2] On the other hand, relatively few measurements[3,5,6] are found in the literature on the behavior of the spectral transmittance as a function of absorber concentration for typical atmospheric conditions. These latter measurements greatly facilitate the validation and development of transmission band models, which are extensively used in a variety of applications such as electrooptical systems design, atmospheric physics, combustion, and air pollution.

Very recently two of the present authors[7] developed a band model for NO from line-by-line transmittance data calculated with the use of the Air Force Geophysics Laboratory line-parameter tape for the trace gases.[8] Instead of adopting a classical band model, as previous workers have,[5,9] use was made of a general transmission function which had been successfully tested earlier with the major atmospheric absorbers.[10] To increase its usefulness, the model was designed for compatibility with the widely accepted computer code LOWTRAN.[11] However, before the model can be fully accepted for realistic prediction schemes, it is mandatory that it be compared (and possibly upgraded) with measured transmittance spectra. The purpose of this paper is to provide the results of such an effort using the measurements of Ford and Shaw.[4]

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II. Background of Band Model

The monochromatic transmittance τ_ν at wave number ν, governing the passage of IR radiation through a path of length Z along a homogeneous medium at pressure P and temperature T, is given by Beer's law in the form

$$\tau_\nu = \exp[-K_\nu(P,T)U(P,T,Z)], \tag{1}$$

where K_ν is the absorption coefficient for all contributing lines of a given absorber, and U is the absorber amount. For broadband radiation detected by an instrument of spectral response Φ_ν, the variable of interest is the weighted mean transmittance τ defined as

$$\tau_\nu = \int \tau_\nu \Phi_\nu d\nu / \int \Phi_\nu d\nu, \tag{2}$$

where the integration is to be carried over the spectral response of the instrument. The evaluation of Eq. (2) through the introduction of various types of assumptions has led to the numerous so-called band models found in the literature.

In a recent study[7,10] Eq. (2) was approximated by a double-exponential function of the form

$$\tau = \exp(-10^{a_1 + a_2 X + a_3 X^2}), \tag{3}$$

in which

$$X = C' + \log_{10} W, \tag{4}$$

$$W = \left(\frac{T_0}{T}\right)^m \left(\frac{P}{P_0}\right)^n U. \tag{5}$$

Here a_1, a_2, a_3, m, and n are constants which depend on the absorber type, C' is a parameter defined over the spectral interval $\Delta\nu$, T_0 and P_0 are the standard temprature and pressure, respectively, and W is the equivalent or effective absorber amount. This model was thoroughly tested for the principal absorbers H_2O vapor, CO_2, and O_3, as well as for the trace gases SO_2, NH_3, NO, and NO_2, and found to be in close conformity with the empirical transmission functions extracted numerically from the same data.

In modeling of the trace gases the data were generated with the AFGL line-parameter tape using Eqs. (1) and (2) through the use of a triangular instrument response function of 20-cm^{-1} FWHM and the Lorentz line shape. The atmospheric profiles allowed for temperature variations in the 257.1–288.1 K range and pressure variations in the 616.0–1013-mbar range for horizontal paths along the various pressure levels of sufficient length as to yield nearly complete transmission curves (i.e., τ vs $\log_{10}U$). The absorber parameters were determined with the data at the band centers for each species, while the spectral parameters were obtained at 5 cm^{-1} with those parameters and the remaining data throughout the entire bands. The parameters for NO were provided in the 1760–1970-cm^{-1} spectral range, which, when substituted in Eqs. (3), (4), and (5), yield an overall standard transmittance deviation of 0.9% from the original synthetic spectra.

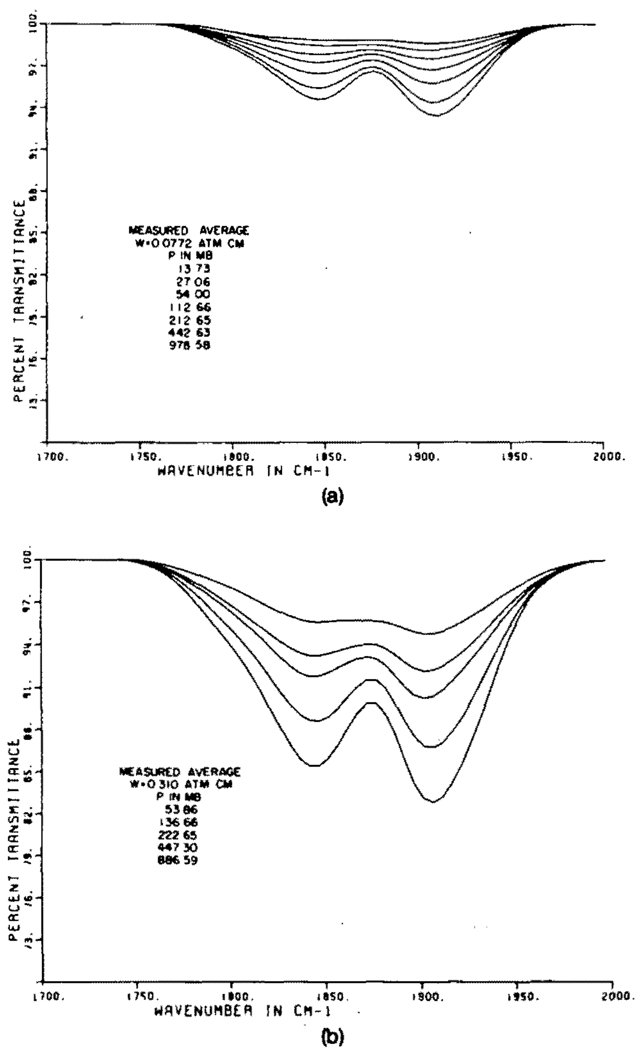

Fig. 1. Spectral transmittance curves at 300 K obtained by degrading the NO measurements of Ford and Shaw[4] at 5-cm^{-1} intervals using a triangular slit functions of 20-cm^{-1} halfwidth.

III. Application to Experimental Data

Of the transmittance measurements for NO available in the literature, the results of Ford and Shaw[4] were adopted in the present study. The data exhibited a total of twelve medium-resolution spectral transmittance curves at 300 K, ranging in pressure from 13.73 to 978.58 mbar for two absorber amounts of 0.0772 and 0.3100 atm cm. For use in the analysis, the curves were enlarged, digitized, and degraded to 20-cm^{-1} halfwidth. The results are shown in Fig. 1.

Calculations were then made using the previously reported NO model for the same conditions as in the experimental data. The results of the comparisons between this model predicted transmittances, and the measurements are shown in Table I. The standard deviations were computed from the difference between the percent transmittance predicted and those measured for all the curves at a given wave number interval. The peak deviations represent the maximum absolute transmittance difference as observed from among all the curves at a given wave number interval. The statistics at the bottom of the table are the simple averages of the values listed under the corresponding columns.

In an effort to upgrade the model, the absorber parameters were redetermined with the use of the experimental data. The numerical techniques adopted were identical to those applied to the earlier model, except that the absorber parameters were obtained from the data in the high absorption region at 1845, 1865, 1975, and 1910 cm^{-1}. In the original development only the transmittance data at 1905 cm^{-1} had been used. Furthermore, it was found that the quadratic term in the exponent of Eq. (3) was no longer needed to guarantee accurate predictive capabilities. Calculations were then made using the new model for the same meteorological conditions as in the experimental data. The results of comparisons between the new model predicted transmittances and the measurements are shown in Table I together with the new spectral parameters. The new values for the absorber parameters are $a_1 = -0.39912$, $a_2 = 0.69057$, and $n = 0.5521$, which should be used in Eqs. (3), (4), and (5) together with the previous value of $m = 1.08785$ and with the new spectral parameters.

Table I. Summary of the Results of Comparisons Between an Earlier Model Development with Synthetic Spectra and the Proposed Development, Which Involves Measured NO Transmittance Data; the Spectral Parameters C' shown in the Rightmost Column Is to be Used with Eqs. (3)–(5) with $a_1 = -0.39912$, $a_2 = 0.69057$, $a_3 = 0$, $n = 0.5521$, and $m = 1.08785$

	TRANSMITTANCE DEVIATIONS FROM MEASUREMENTS (%)				
WAVE-NUMBER (CM^{-1})	PREVIOUS MODEL STANDARD	PREVIOUS MODEL PEAK	PRESENT MODEL STANDARD	PRESENT MODEL PEAK	SPECTRAL PARAMETER FOR PRESENT MODEL, C´
1700	0.00	0.01	0.01	0.03	-4.108
1705	0.00	0.01	0.01	0.02	-4.108
1710	0.00	0.01	0.01	0.02	-4.108
1715	0.00	0.01	0.01	0.02	-4.108
1720	0.00	0.01	0.01	0.02	-4.108
1725	0.00	0.01	0.01	0.02	-4.108
1730	0.00	0.01	0.01	0.02	-4.108
1735	0.00	0.01	0.01	0.02	-4.108
1740	0.01	0.02	0.01	0.01	-3.988
1745	0.03	0.08	0.01	0.03	-3.408
1750	0.08	0.19	0.03	0.06	-2.917
1755	0.18	0.40	0.11	0.24	-2.869
1760	0.26	0.52	0.20	0.42	-2.526
1765	0.43	0.86	0.32	0.64	-2.202
1770	0.65	1.29	0.36	0.72	-1.776
1775	0.88	1.76	0.37	0.72	-1.435
1780	1.14	2.25	0.35	0.67	-1.171
1785	1.38	2.69	0.32	0.58	-0.964
1790	1.58	2.99	0.30	0.51	-0.801
1795	1.73	3.09	0.29	0.59	-0.669
1800	1.81	3.14	0.29	0.68	-0.558
1805	1.81	3.07	0.28	0.78	-0.455
1810	1.77	2.90	0.29	0.86	-0.362
1815	1.69	2.80	0.29	0.90	-0.275
1820	1.60	2.73	0.30	0.90	-0.197
1825	1.51	2.60	0.32	0.86	-0.130
1830	1.43	2 38	0.34	0.77	-0.074
1835	1.39	2.07	0.36	0.67	-0.031
1840	1.40	2.43	0.37	0.68	-0.006
1845	1.50	3.27	0.36	0.69	-0.001
1850	1.61	3.87	0.33	0.65	-0.012
1855	1.59	3.73	0.32	0.58	-0.039
1860	1.62	3.64	0.39	0.83	-0.074
1865	1.58	2.65	0.52	1.27	-0.111
1870	1.70	2.88	0.61	1.48	-0.137
1875	1.81	3.16	0.62	1.40	-0.141
1880	2.03	3.49	0.55	1.39	-0.113
1885	2.01	3.44	0.45	1.33	-0.056
1890	1.82	3.03	0.38	1.19	-0.008
1895	1.65	2.46	0.38	0.96	0.062
1900	1.68	3.42	0.42	0.71	0.097
1905	1.85	4.26	0.47	0.82	0.107
1910	1.98	4.81	0.50	0.89	0.094
1915	1.96	4.94	0.51	0.95	0.063
1920	1.76	4.49	0.48	0.98	0.013
1925	1.47	3.45	0.45	0.93	-0.054
1930	1.27	2.22	0.42	0.82	-0.138
1935	1.26	1.95	0.40	0.76	-0.243
1940	1.32	2.12	0.38	0.92	-0.371
1945	1.36	2.10	0.38	1.00	-0.521
1950	1.29	2.06	0.34	0.92	-0.698
1955	1.12	1.83	0.28	0.72	-0.905
1960	0.91	1.49	0.23	0.45	-1.145
1965	0.70	1.15	0.19	0.35	-1.429
1970	0.50	0.83	0.19	0.37	-1.798
1975	0.35	0.63	0.16	0.31	-2.228
1980	0.20	0.38	0.14	0.23	-2.895
1985	0.10	0.19	0.04	0.07	-2.850
1990	0.04	0.08	0.02	0.04	-3.192
1995	0.01	0.03	0.01	0.01	-4.079
AVERAGE	1.05	1.98	0.28	0.61	

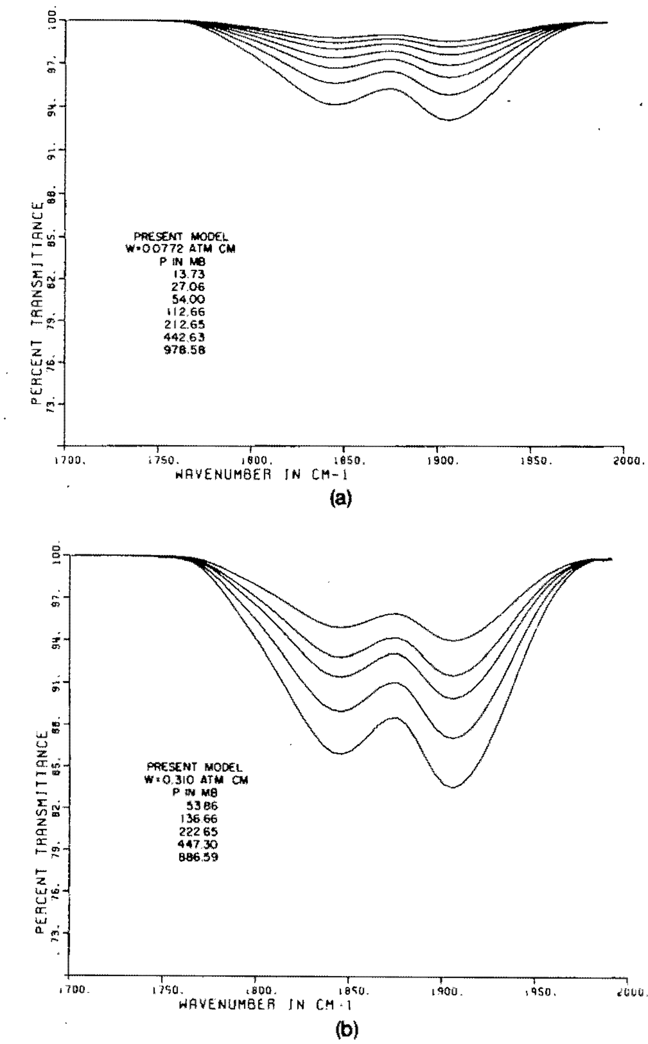

Fig. 2. Spectral transmittance curves at 300 K obtained from the NO model in Eqs. (3), (4), and (5) together with the newly proposed absorber and spectral parameters.

Spectral curves for conditions corresponding to those in Fig. 1 were plotted and depicted in Fig. 2.

IV. Discussion and Conclusions

Validation and upgrading have been presented of a double-exponential model proposed in an earlier paper for gaseous transmittance in the fundamental absorption band of NO. The model had been developed with line-by-line calculated transmittance data, and the parameters had been provided to allow for predictions at 5-cm^{-1} intervals with a 20-cm^{-1} spectral resolution. Although the modeling resulted in a standard deviation of 0.8%, the data itself were only for pressures in the 257.1–288.1 K range.

The validation was accomplished by comparisons with the well-known medium-resolution transmittance measurements of Ford and Shaw.[4] The data consisted of twelve spectral curves at room temperature at pressures ranging from 13.73 to 978.58 mbar for two NO amounts of 0.0772 and 0.3100 atm cm. After spectrally degrading the data, they were compared with the model calculated transmittance yielding an average standard deviation of 1.05% and an average maximum deviation of 1.98%. On a statistical basis, therefore, the model may be considered to be of sufficient accuracy for predictions in real life environments. On a point-by-point comparison, however, it was found that at 1915 cm^{-1} the bottom curve on Fig. 1(b) differed by 4.94% from the predictions. This may be deemed as a relatively large difference considering that the measured absorption at that wave number is only 16.66%. Assuming that the functional form of the model adopted is the appropriate choice for NO, some factors which, acting either individually or collectively, may be suggested as having a major influence on the observed results are:

(1) The relatively high statistical accuracy of the model was not sufficient for insuring correspondingly small individual transmittance differences.

(2) The model was applied to conditions significantly beyond the range of the data used in its development. (Measurements are mostly in the linear region after being degraded.)

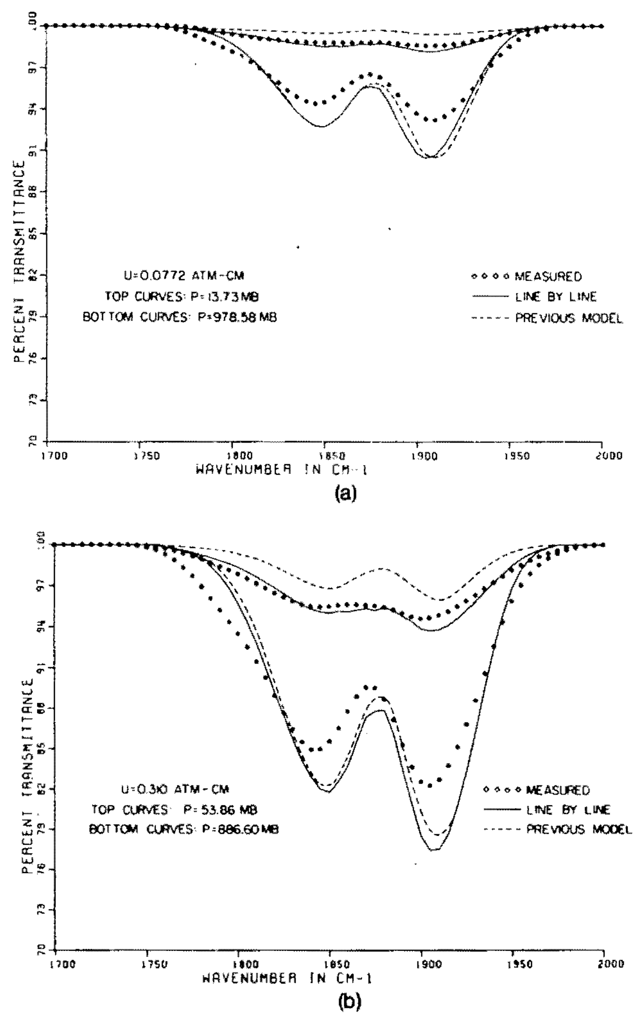

Fig. 3. Spectral curves representing a comparison between the measurements, the degraded line-by-line calculations, and the previously published model for (a) $U = 0.0772$ atm cm and (b) $U = 0.310$ atm cm.

(3) The adoption of the Lorentz line shape in the data generation may not have been sufficiently justified.[12]

(4) The error tolerances of the line parameters adopted may not have allowed for transmittance calculations with any higher degree of certainty than those observed in the comparison with the measurements for long paths.

(5) The measured transmittance may possess uncertainities comparable to the observed differences.

Since the first four possible justifications listed are inherent to the model development and to the developing data, it was decided to redevelop the model parameters with the available measurements. Even though the temperature dependence of the original model was assumed, the numerical procedures were improved with the simultaneous use of four spectral intervals in the determination of the remaining model parameters. As seen in Table I, the adoption of the new parameters allows on the average for a reduction of the transmittance differences by a factor of nearly 4. The overall peak deviation was found to be 1.48% at 1870 cm^{-1} for the same meteorological conditions as those associated with the previous model overall peak deviation.

With respect to the factors listed above it should be realized that the spectral curve where the 4.94% error was observed corresponds to an absorber amount 700 times larger than that expected for a vertical path through the entire atmosphere at typical NO concentrations. To investigate the closeness of the line-by-line calculations to the measured transmittances, four transmittance curves were computed and compared with the measurements as well as with the previously published model. The results of this comparison are shown in Fig. 3, where the curves represent the conditions for the measurements shown as the top and bottom curves of Figs. 1(a) and (b), respectively. It may be proposed that the differences between the model and the measurements for lower pressures are due to the fact that the model was being applied to conditions far beyond the range of the developing data. On the other hand, the corresponding differences at the higher pressures may be attributed to differences between the measurements and the degraded line-by-line calculations. These latter differences should not be of any concern to model users because they are easily justified in terms of the exceedingly abnormal atmospheric conditions they represent. In any event, the mean standard deviation for the four curves amounted to 0.91%, with an overall peak of 5.15% at 1910 cm^{-1}.

In summary, a model has been presented whose parameters have been determined by a combination of measured spectra (for a_1, a_2, n, and C') and synthetic spectra (for m only). Since the model is more accurate, requires fewer parameters, and was developed with improved numerical techniques using primarily experimental data, it is recommended for adoption in place of the earlier version.

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Validated band model for NO_2 molecular transmittance in the infrared

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A previously reported transmittance model for nitrogen dioxide in the two fundamental bands ν_2 and ν_3, plus the combination band $\nu_1 + \nu_3$, is now presented using upgraded synthetic spectra and measured data. The model consists of a well-established double-exponential function which approximates homogeneous path transmittance at 5-cm^{-1} intervals with a spectral resolution of 20 cm^{-1}. Its parameters and other computational features are developed for direct compatibility with the widely used AFGL LOWTRAN code. Transmittance calculations in the range from zero to unity deviate on the average ~0.84% from a combination of synthetic and measured spectra, which constitutes an improvement over the previously reported model.

I. Introduction

Nitrogen dioxide (NO_2) is an atmospheric trace gas which reaches typical concentrations of 1 ppmv (parts/million by volume) near the earth's surface[1] and higher values near polluted environments[2] and at stratospheric heights.[3] Of the two fundamental bands, ν_2 at 750 cm^{-1} and ν_3 at 1617 cm^{-1}, the latter is the strongest and also overlaps a region of water-vapor absorption. The combination band $\nu_1 + \nu_3$ is located at 2910 cm^{-1} in the 3.4-μm atmospheric window region. Although a comprehensive tabulation of the line parameters for these absorption bands has been available for some time,[4] neither transmittance calculations using these parameters nor comparisons with measurements have been reported to any significant extent in the literature. With regard to the measurements, very few are found in the literature[5-7] depicting the spectral transmittance as a function of the absorber amount. These latter types of data greatly facilitate the validation and development of transmission band models such as LOWTRAN[8] for use in a variety of scientific, industrial, and military applications.

Very recently the present authors[9] proposed a band model for NO_2, which was developed using strictly synthetic spectra as obtained with the use of the AFGL compilation. In the work reported now the authors reexamined the algorithm adopted earlier in the line-by-line calculations and redeveloped the NO_2 band model using a combination of synthetic and measured spectra. The measurements adopted were those of Burch *et al.*[7] for 1617 cm^{-1} at pressures of 1 atm or below. The mathematical expression for the new model itself is simpler than the one proposed earlier, and its computational accuracy is higher. The results are presented for a resolution of 20 cm^{-1}, with spectral parameters provided at 5-cm^{-1} intervals in a manner suitable for incorporation into the LOWTRAN code.

II. Band Model Concept

The monochromatic transmittance τ_ν at wave number ν governing the passage of IR radiation through a path of length Z along a homogeneous medium at pressure P and temperature T is given by Beer's law in the form

$$\tau_\nu = \exp[-K_\nu(P,T)U(P,T,Z)], \quad (1)$$

where K_ν is the absorption coefficient for all contributing lines of a given absorber, and U is the absorber amount. For broadband radiation detected by an instrument of spectral response Φ_ν, the variable of interest is the weighted mean transmittance τ defined as

$$\tau = \int \tau_\nu \Phi_\nu d\nu / \int \Phi_\nu d\nu, \quad (2)$$

where the integration is to be carried over the spectral response of the instrument. The evaluation of Eq. (2) through the introduction of various types of assumption concerning the line structures has led to the numerous so-called band models found in the literature. A rigorous numerical evaluation of Eq. (2) summing up all significant lines contributing to the transmittances within the integration limits is called the line-by-line[10] method. The data thus generated are of essential value in the determination of band model parameters. In the

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calculation of τ_i use is commonly made of a triangular response function Φ_ν of full width $\Delta\nu$ at the half-intensity level centered at ν_i, and all significant lines within $\pm 40\ cm^{-1}$ of ν_i are included. The calculations are repeated at intervals of $5\ cm^{-1}$ throughout the band spectrum.

A series of recent studies[9,11-13] has indicated that the atmospheric transmittance averaged over a spectral interval $\Delta\nu$ within an absorption band can be accurately represented by the double-exponential function

$$\tau = \exp[-10^{a_1 + a_2 X + a_3 X^2}], \tag{3}$$

where

$$X = C'(\Delta\nu) + \log_{10} W, \tag{4}$$

$$W = \left(\frac{P}{P_o}\right)^n \left(\frac{T_o}{T}\right)^m U. \tag{5}$$

Here a_1, a_2, a_3, n, and m are model constants which depend only on the absorber type; C' is a spectral parameter which depends on $\Delta\nu$; W is the equivalent absorber amount; and the subscript o denotes standard conditions of the meteorological parameters. This function has been successfully applied[12] to the principal bands of H_2O vapor, O_3, a combination of CO_2 and the uniformly mixed gases, as well as to the trace gases SO_2, NH_3, NO_2, and NO.[9] The latter model was very recently validated[13] using the measurements of Ford and Shaw.[14]

Since the model parameters for a given absorber are to be spectrally independent, the numerical procedures used in their determination not only must include data from all bands of interest but also must generate all the parameters simultaneously. For this purpose the square difference error E_{ik} for the ith spectral interval and the kth datum may be defined as

$$E_{ik} = [\tau_{ik} - \exp(-10^{a_1 + a_2 X_{ik} + a_3 X_{2ik}})]^2, \tag{6}$$

in which

$$X_{ik} = n \log_{10}\left(\frac{P_{ik}}{P_o}\right) + m \log_{10}\left(\frac{T_o}{T_{ik}}\right) + \log_{10} U_{ik} + \upsilon_{1,ik} C'(\Delta\nu_1) + \upsilon_{2,ik} C'(\Delta\nu_2) + \ldots + \upsilon_{I,ik} C'(\Delta\nu_I). \tag{7}$$

Here, the various υ are auxiliary variables which attain the value of either one or zero depending on whether the developing data are for that spectral interval. In addition, I represents the total number of spectral intervals used in the simultaneous extraction of the model parameters. The grand total error E over all the data K and the I spectral intervals follows from Eq. (6) as

$$E = \sum_{i=1}^{I} \sum_{k=1}^{K} E_{ik}. \tag{8}$$

The minimization of E in the solution of Eq. (8) for the optimal parameters set $[n,m,C'(\Delta\nu),\ldots,C'(\Delta\nu_I),a_1,a_2,a_3]$ may be accomplished with the use of the conjugate gradient algorithm available as a package subroutine in the IBM SSP library.[9,15] This optimal parameter set may then be used in the determination of the various C' for each remaining spectral interval within all the absorption bands. Taking the logarithm of Eq. (3) twice leads to the quadratic equation

$$a_3 X_{ik}^2 + a_2 X_{ik} + a_1 - \log_{10}(-\ln \tau_{ik}) = 0, \tag{9}$$

the smaller root if $a_3 < 0$ and the larger one if $a_3 > 0$, which gives the desired solution for X_{ik}. Using this X_{ik}, solving Eq. (4) for $C'(\Delta\nu_i)$, and computing the average over all the data for that spectral interval yield

$$C'(\Delta\nu_i) = \frac{1}{K} \sum_{k=1}^{K} [X_{ik} - \log_{10} W_{ik}]. \tag{10}$$

In the event that sufficient accuracy is obtained conserving only up to the linear term in the X polynomial of Eq. (3), $a_3 = 0$ and the optimal parameters may be easily determined through the use of least-squares methods.

III. Transmittance Data

Because of the ready availability of the line parameter compilation of atmospheric gases and of user-oriented computational codes, synthetic spectra are commonly used in the development of molecular transmission models. Generally speaking, the transmittance data are generated using Eqs. (1) and (2), with a triangular instrument function ϕ_ν of halfwidth $\Delta\nu$, and adopting an absorption coefficient K_ν, which corresponds to the atmospheric region of interest. Horizontal paths are then selected along several pressure levels of some model atmosphere[16] at typical absorber concentrations in such a way that complete curves-of-growth (i.e., τ vs $\log_{10} U$) are generated at each $\Delta\nu$. For the purpose of reducing the computation time and the memory storage requirements, some lines are frequently excluded through constraining algorithms based on the line intensities or on their spectral separation from the frequency ν, at which time the calculations are made. However, for the models to be of significant value to electrooptical designers it is imperative that they be validated with experimental data.

In the previously published[9] model for NO_2 these authors used strictly line-by-line spectral data generated with a modified version of the LASER[17] code and incorporating an earlier version of the AFGL line parameter tape for the trace gases.[4] This code restricted the number of contributing lines based on the line intensities and excluded the remaining lines, which were located further than $\pm 20\ cm^{-1}$ from the wave number of interest. The data were then spectrally degraded with a filter function of $20\text{-}cm^{-1}$ full width at half-intensity before they were used in transmittance modeling, and in this paper they are referred to as the old line-by-line data. In the present analysis these data were compared with the spectral measurements of Burch *et al.*[7] in the fundamental band centered at $1617\ cm^{-1}$ for pressures ranging from 0.1 to 1 atm. The measurements were spectrally degraded to the same resolution as the calculated data. Figure 1 depicts several of the original spectral curves before degrading which were measured with a slit width varying from ~ 0.61 to $0.67\ cm^{-1}$.

Figure 2 shows spectrally degraded transmittance samples establishing a comparison between two types of line-by-line calculation and the measured data for sample 4 of Fig. 1. The new line-by-line curve repre-

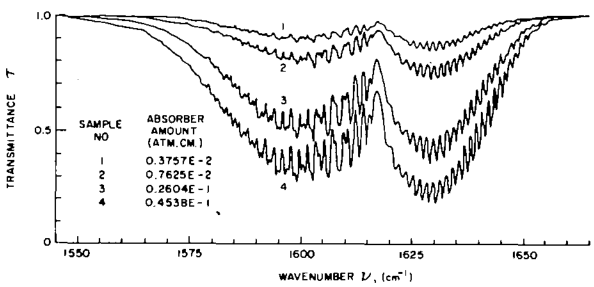

Fig. 1. Samples of measured monochromatic transmittance data[7] for NO_2 at a total pressure of 1 atm and a temperature of 320 K for various absorber amounts.

sents calculations with a computer code that accepts all contributing lines regardless of their intensities within ± 40 cm^{-1} of the wave number of interest and uses the most recent version of the AFGL line parameter compilation.[18] To reduce computer storage requirements this code makes use of a line processing algorithm similar to the one incorporated into the AFGL code called FASCODE.[10] The latter was not used because, being a general atmospheric transmission code, it accounts for a wide variety of attenuation effects other than molecular transmittance, and the output was not in a form desirable for modeling. The old line-by-line data were found to be within an overall rms deviation of 4.3% from the measurements, with a peak deviation of 9.79%, while the new line-by-line data were within 1.19%, with a peak of 2.45%. Since the major discrepancy between the two calculated transmittance data was in the wings of the band, it may be reasonably postulated that it was caused by the previous exclusion of weak lines in the calculations. Although not shown, the other two bands manifested a very analogous behavior.

IV. Band Model for NO_2

The proposed model and associated numerical methods were applied to the new synthetic spectra as well as to the measured spectra. The ten samples used were those from the Burch *et al.*[7] data for the 1617-cm^{-1} band measured at pressures ranging from 0.1 to 1 atm. In Eq. (5) the absorber amount U may be computed from the definition $U = \rho_g Z$, where ρ_g is the absorbing gas density, and Z is the path length which, with the proper changes of units,[12] becomes

$$U(\text{atm cm}) = 0.7732 \times 10^{-4} \text{ ppmv } \rho_a(\text{gm/m}^3)Z(\text{km}), \quad (11)$$

with ρ_a being the air density.

The optimal model parameters a_1, a_2, n, and m were determined simultaneously with C' for wave numbers 730, 1620, 1625, and 2900 cm^{-1} using a mixture of synthetic and measured spectral data. Several trials were made with other spectral intervals, but the trial for these intervals and with a_3 set equal to zero gave the best results. The values of the optimal parameters obtained are $a_1 = -0.25653$, $a_2 = 0.88674$, $n = 0.14859$, and $m = 0.55832$. Their determination was made first using least-squares techniques, and the results thus obtained were treated as initial guesses for the nonlinear minimization established by Eq. (6). The remaining C' for all three bands were then determined with these optimal parameters and with the use of Eqs. (9) and (10).

The optimal spectral parameters at 5 cm^{-1} over the entire bands are tabulated in Table I. The table also includes the rms deviations of the transmittances computed using the present model from a mixture of the new synthetic spectra and the measurements on the 1617-cm^{-1} fundamental. The overall rms transmittance deviation is 0.84%. Figures 3–5 show spectral curves generated with the present model and compared with the mixed data for the three bands at the meteorological conditions stipulated.

To use the absorption model coefficients and the transmittance function provided in atmospheric calculations it is necessary to employ a vertical altitude profile of the absorber concentration. These profiles may provide the ppmv needed in Eq. (11) to compute the absorber amount along a given path. Although a more precise analysis would require knowledge of latitudinal and seasonal variations,[3] for general transmittance estimates an average profile may be sufficient. For the layered atmospheres of LOWTRAN the authors recommend the vertical profile for NO_2 listed in Table II, which was obtained from Ref. 19 through linear scaling to the desired altitudes.

V. Conclusion

A revised model has been presented for the calculation of transmittance through atmospheric NO_2 in the 750-, 1617-, and 2906-cm^{-1} bands at 20-cm^{-1} resolution. A double-exponential function has been assumed with a single spectral parameter in a manner suitable for immediate adoption into the LOWTRAN code.[8] An overall rms deviation of <1% is obtained when the model is compared to the developing data. The developing data themselves are a mixture of line-by-line data computed using the latest AFGL line parameter tape including all lines within ± 40 cm^{-1} of the frequency of interest and extensive measurements in the 1617-cm^{-1} band by Burch *et al.*[7] The revised model replaces a version published earlier which had been developed strictly with synthetic spectra and which excluded weak lines as well as new lines which appeared in later versions of the AFGL line parameter compilation.

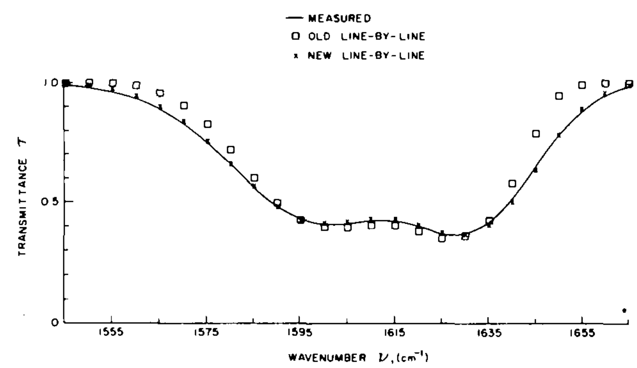

Fig. 2. Spectral transmittance calculations compared with a measured NO_2 sample[7] at a total pressure of 1 atm and a temperature of 328 K for an absorber amount of 0.4538×10^{-1} atm cm.

Table I. Summary of the Results of Comparisons Between a Mixture of Line-by-Line and Measured Transmittance Data and the Proposed Model; Spectral Parameter C' Given is to be Used with Eqs. (3)–(5) with $a_1 = -0.25653$, $a_2 = 0.88674$, $a_3 = 0$, $n = 0.14859$, and $m = 0.55832$

WAVE NUMBER (CM^{-1})	SPECTRAL PARAMETER C' $(ATM.CM)^{-1}$	RMS TRANSMITTANCE DEVIATIONS FROM MIXED DATA (%)	WAVE NUMBER (CM^{-1})	SPECTRAL PARAMETER C' $(ATM.CM)^{-1}$	RMS TRANSMITTANCE DEVIATIONS FROM MIXED DATA (%)
655	-2.455	0.610	1550	-2.222	0.400
660	-2.358	0.613	1555	-1.744	0.456
665	-2.269	0.620	1560	-1.370	0.421
670	-2.199	0.572	1565	-1.061	0.438
675	-2.125	0.503	1570	-0.804	0.490
680	-2.082	0.456	1575	-0.584	0.490
685	-2.026	0.545	1580	-0.396	0.569
690	-1.988	0.715	1585	-0.243	0.673
695	-1.961	0.829	1590	-0.129	0.832
700	-1.900	1.228	1595	-0.056	1.179
705	-1.875	1.111	1600	-0.031	1.500
710	-1.814	1.079	1605	-0.041	1.586
715	-1.743	1.082	1610	-0.057	1.597
720	-1.709	0.806	1615	-0.056	1.651
725	-1.649	0.856	1620	0.0	1.039
730	-1.637	0.933	1625	0.043	1.288
735	-1.673	0.938	1630	0.029	2.082
740	-1.707	1.096	1635	-0.023	1.431
745	-1.763	1.157	1640	-0.147	1.095
750	-1.791	1.145	1645	-0.352	0.821
755	-1.751	1.356	1650	-0.638	0.389
760	-1.680	1.488	1655	-1.016	0.364
765	-1.636	1.375	1660	-1.506	0.338
770	-1.608	1.206	1665	-2.219	0.243
775	-1.607	1.120	1670	-2.619	0.062
780	-1.661	1.024	2840	-3.575	0.077
785	-1.710	1.090	2845	-3.220	0.145
790	-1.751	1.390	2850	-2.891	0.248
795	-1.814	1.333	2855	-2.589	0.390
800	-1.849	1.314	2860	-2.314	0.561
805	-1.873	1.347	2865	-2.068	0.743
810	-1899	1.259	2870	-1.856	0.927
815	-1.919	1.109	2875	-1.680	1.095
820	-1.940	0.974	2880	-1.544	1.275
825	-1.957	0.914	2885	-1.454	1.507
830	-1.995	0.671	2890	-1.416	1.619
835	-2.023	0.605	2895	-1.413	1.593
840	-2.054	0.561	2900	-1.413	1.387
845	-2.090	0.493	2905	-1.394	1.006
850	-2.130	0.453	2910	-1.346	0.832
855	-2.171	0.436	2915	-1.308	0.827
860	-2.213	0.429	2920	-1.329	0.923
865	-2.264	0.423	2925	-1.427	1.108
870	-2.310	0.432	2930	-1.620	1.063
875	-2.359	0.436	2935	-1.922	0.678
880	-2.406	0.456	2940	-2.344	0.390
1540	-2.666	0.036	2945	-2.943	0.129
1545	-2.975	0.280	2950	-3.832	0.034

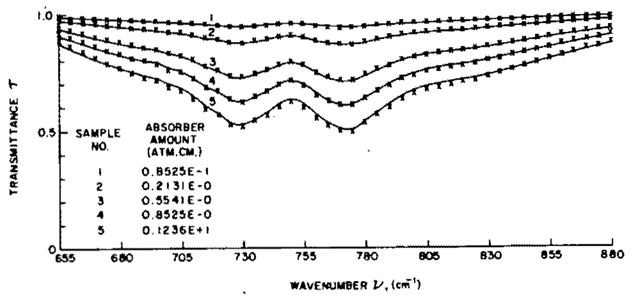

Fig. 3. Spectral transmittance comparisons between the new line-by-line calculations (—) and the proposed optimal model (XX) for the $NO_2\nu_2$ band at 1 atm of total pressure and a temperature of 288.1 K for various absorber amounts.

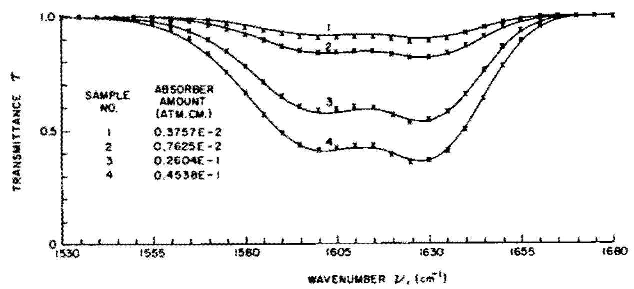

Fig. 4. Spectral transmittance comparisons between a mixture of new line-by-line calculations and measurements[7] (—) and the proposed optimal model (XX) for the $NO_2\nu_3$ band at 1 atm of total pressure and a temperature of 328 K for various absorber amounts.

Table II. Recommended Vertical Mixing Ratio Profile for NO_2 for the Atmospheric Layers in LOWTRAN[21]

HEIGHT (KM)	PARTS PER MILLION BY VOLUME (PPMV)	HEIGHT (KM)	PARTS PER MILLION BY VOLUME (PPMV)
0	0.3000E-03	17	0.3750E-03
1	0.3000E-03	18	0.4000E-03
2	0.3000E-03	19	0.6500E-03
3	0.3000E-03	20	0.9000E-03
4	0.3000E-03	21	0.1050E-02
5	0.3000E-03	22	0.1200E-02
6	0.3000E-03	23	0.1700E-02
7	0.3000E-03	24	0.2200E-02
8	0.3000E-03	25	0.2650E-02
9	0.3000E-03	30	0.7500E-02
10	0.3000E-03	35	0.5250E-02
11	0.3000E-03	40	0.3500E-02
12	0.3000E-03	45	0.2250E-02
13	0.3150E-03	50	0.1000E-02
14	0.3300E-03	70	0.1000E-02
15	0.3400E-03	100	0.1000E-02
16	0.3500E-03		

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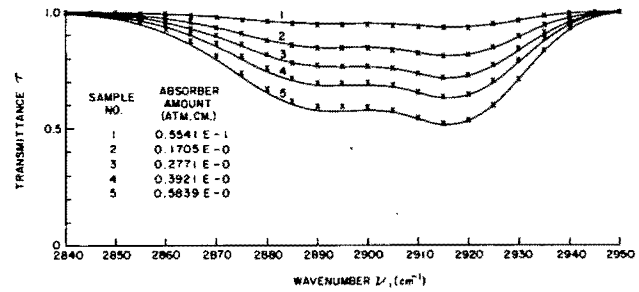

Fig. 5. Spectral transmittance comparisons between the new line-by-line calculations (—) and the proposed optimal model (XX) for the $NO_2\nu_1 + \nu_3$ band at 1 atm of total pressure and a temperature of 288.1 K for various absorber amounts.

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Validated transmittance band model for SO_2 in the infrared

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A band model is presented for the calculation of atmospheric molecular transmittance through sulfur dioxide (SO_2) in the infrared region. It consists of a well-established double-exponential function defined by three absorber-dependent parameters and a single spectrally dependent parameter. The parameters are determined by an optimal numerical procedure which incorporates a mixture of line-by-line calculated transmittance data and laboratory measurements. The developing data are degraded to 20-cm^{-1} resolution spectral averages repeated at 5-cm^{-1} intervals for easy adaptability with the LOWTRAN code. A diurnally and seasonally averaged mixing ratio profile for SO_2 is proposed for use with the thirty-three layer standard atmosphere models. The proposed band model reproduces the developing data with an average rms error of 2.37%.

I. Introduction

The study of atmospheric sulfur dioxide (SO_2) is rapidly expanding because it is a pollutant of primarily anthropogenic origin. It is brought into the earth's atmosphere mainly by the burning of fossil fuels and by certain smelting and refining industries.[1] For this reason it has been singled out as an industrial pollutant of concern, and great efforts are being made to measure its vertical atmospheric concentration.[2] In the atmosphere it may be converted, for example, into sulfate-containing aerosol particles which can modify the earth's radiation balance as well as the precipitation forming ability and optical properties of the air. Because of its absorptive characteristics in the infrared, it has been included as one of the four trace gases whose parameters are listed in the Air Force Geophysics Laboratory Line Parameter Compilation.[3] These data include the three fundamental bands ν_1 at 1152 cm^{-1}, ν_2 at 517 cm^{-1}, and ν_3 at 1362 cm^{-1} as well as the combination band $\nu_1 + \nu_3$ at 2500 cm^{-1}. The latter band, although the weakest, is of interest because of its isolation from other absorption bands, thus offering itself for possible remote sensing applications.

In earlier modeling efforts,[4] use was made of a double-exponential function, together with a somewhat limited numerical procedure for parametrization, to arrive at a band model for SO_2 transmittance. The numerical procedures involved the determination of the absorber parameters using strictly line-by-line calculated transmittances at only four spectral intervals, one from each of the four absorption bands. The spectral location of the intervals within the individual bands was chosen by trial and error on the basis of minimum absolute deviation between the model recalculations and the original transmittance data. The remaining spectral parameters were then determined using the absorber parameters available and taking averages from the data at each wave-number interval. In the present work the transmittance function was slightly modified, the parametrization was replaced with a recently proposed numerical method,[5] and the developing data were made to include laboratory measurements by Burch *et al.*[6]

II. Fundamental Equations

Since the discovery of the infrared region of the spectrum by Herschel,[7] an ever increasing number of instruments and systems have been conceived which depend on a knowledge of atmospheric transmittance for design and implementation. The physical and chemical processes involved in the absorption of infrared energy by the molecules of the gases in the atmosphere are generally well understood. Monochromatic absorption is governed by Beer's[8] law, and the broadening of the absorption lines is described by functions such as Doppler,[9] Lorentz,[10] and Voigt[11] shapes. Hence, the method of synthesizing atmospheric molecular absorption along a specified path reduces itself to basically the application of those

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functions to known or assumed information on the absorbing gas types, their concentration, the meteorological conditions, the path geometry, the instrument spectral response, and the line parameters.

According to Beer's law the monochromatic transmittance τ_ν at wave number ν governing the passage of infrared radiation through a path of length Z along an inhomogeneous medium with pressure and temperature distributions $P(Z)$ and $T(Z)$, respectively, is given by

$$\tau_\nu = \exp[-\int K(P,T)dU(Z)], \tag{1}$$

where the integration is to be carried over the path length, K is the absorption coefficient for all contributing lines of a given absorber, and U is its absorber amount expressible as

$$dU = \rho(Z)dZ, \tag{2}$$

where ρ is the absorber density. For broadband radiation detected by an instrument of spectral response ϕ_ν, the quantity of interest is the weighted mean transmittance τ defined as

$$\tau = \int \tau_\nu \phi_\nu d\nu / \int \phi_\nu d\nu, \tag{3}$$

in which the integration is to be carried over the limits of ϕ. In line-by-line monochromatic calculations of τ_ν in Eq. (1), the approximation is commonly made of a horizontally stratified atmosphere throughout each layer of which uniformity of all parameters may be assumed, such that Eq. (1) becomes

$$\tau_\nu = \exp[-K(P,T)U(Z)]. \tag{4}$$

Equations (3) and (4) have been evaluated over the years for spectral intervals containing from one[12] to numerous lines with assumed line shapes and distributions of intensities and spectral positions.[13–15] Numerous analytical and empirical variations of these classical approaches may be found in the literature,[16] most of which express τ in terms of absorber and spectral parameters, as well as meteorological variables, a notable form of these being the King model[17] given by

$$\tau = g(S\alpha^n U), \tag{5}$$

where g is a function and n is a constant which are determined empirically, while S is the mean line intensity and α is the mean line halfwidth over the band. The argument of g in Eq. (5) may be interpreted as a form of the scaling approximation used in the calculation of heating rates by an earlier worker.[18] The path inhomogeneity may be approximately accounted for through the Curtis-Godson equivalence relations[19,20]

$$S\alpha^n U = \int S(Z)\alpha^n(Z)dU(Z), \tag{6}$$

in which n may be assumed to be zero or unity in the weak-line and strong-line limits, respectively.

For practical considerations it is often desirable to transform the argument in Eq. (5) with the assistance of the commonly used relations

$$S = S_0(T_0/T)^b, \tag{7}$$

$$\alpha = \alpha_0(P/P_0)(T_0/T)^{1/2}, \tag{8}$$

where b is an absorber constant, and the subscript 0 denotes standard conditions, which leads to the expression

$$\tau = g[C(P/P_0)^n(T_0/T)^m U]. \tag{9}$$

Here C is a spectral parameter defined over the spectral interval $\Delta\nu$ and combining S_0 and α_0^n, and m is an absorber parameter representing all the temperature-dependent powers. For computational convenience Eq. (9) may be rewritten as

$$\tau = f\{X\}, \tag{10}$$

where

$$X = C' + \log_{10}W, \tag{11}$$

$$C' = \log_{10}C, \tag{12}$$

$$W = (P/P_0)^n(T_0/T)^m U, \tag{13}$$

and f is the transmittance function, C' is a spectral parameter, W is the equivalent absorber amount, and n and m are the absorber parameters.

From the numerous forms of f in Eq. (10), a function that has been found[4] to approximate reasonably well the transmittance of a variety of gases over a wide range of meteorological conditions is the double exponential

$$\tau = \exp(-10^{aX}), \tag{14}$$

where a is an absorber parameter. This function is appealing for use as a universal transmission function because it is asymptotic to one and zero as the argument ranges from $-\infty$ to ∞. With Eqs. (11)–(13) it provides a general band model function defined by three absorber parameters (a,n,m) and a single spectral parameter (C'). It has been shown in the literature[21] that Eq. (14) leads to a transmittance polynomial proposed earlier[22] for carbon dioxide and water vapor, which, in turn, arose from the strong-line limit to the random model.[15] However, because of the substantive number of empirical adjustments made to the theory, not much physical significance may be attributed to the values for the parameter set.

The parameters a, n, and m for the combined spectral bands of an absorber and the C' for each spectral interval may be obtained numerically from transmittance data τ and the meteorological conditions by minimizing the square error ϵ as given by

$$\epsilon = \sum_i \sum_j [\tau(i,j) - \tau_M(i,j)]^2, \tag{15}$$

where $i = 1,2,\ldots, I$ is the number of spectral intervals, $j = 1,2,\ldots, J$ is the number of data values, and τ_M is defined by Eq. (14). The method adopted in connection with Eq. (15) consisted first of minimizing ϵ with respect to a, n, and m and then using the results to minimize ϵ again with respect to the C'_i. Since the equations are nonlinear, the method of conjugate gradient descent was used in the minimization, as provided by the IBM SSP library routines. The results from a linearized version of Eq. (15) were used as initial guesses in the nonlinear determination of the model parameters. The mathematical details of the procedures involved

Table I. Spectral Parameters for SO_2 for Use with Eqs. (11)–(14), as Determined with a Mixture of Line-by-Line and Measured Transmittance Spectra of 20-cm^{-1} Resolution

WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'	WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'	WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'
400	-5.820	540	0.036	1075	-1.765
405	-5.820	545	-0.043	1080	-1.549
410	-5.820	550	-0.133	1085	-1.341
415	-5.820	555	-0.217	1090	-1.141
420	-5.174	560	-0.295	1095	-0.952
425	-4.422	565	-0.374	1100	-0.774
430	-3.737	570	-0.459	1105	-0.609
435	-3.092	575	-0.557	1110	-0.461
440	-2.520	580	-0.673	1115	-0.334
445	-2.030	585	-0.813	1120	-0.224
450	-1.631	590	-0.980	1125	-0.131
455	-1.306	595	-1.183	1130	-0.068
460	-1.037	600	-1.433	1135	-0.042
465	-0.819	605	-1.735	1140	-0.051
470	-0.639	610	-2.106	1145	-0.073
475	-0.488	615	-2.570	1150	-0.080
480	-0.357	620	-3.124	1155	-0.048
485	-0.237	625	-3.769	1160	0.003
490	-0.124	630	-4.572	1165	0.034
495	-0.026	635	-5.462	1170	0.025
500	0.025	640	-5.820	1175	-0.030
505	0.019	645	-5.820	1180	-0.117
510	-0.019	650	-5.820	1185	-0.212
515	-0.066	1050	-3.231	1190	-0.301
520	-0.064	1055	-2.846	1195	-0.383
525	-0.006	1060	-2.520	1200	-0.461
530	0.047	1065	-2.241	1205	-0.539
535	0.068	1070	-1.994	1210	-0.618

Table II. Spectral Parameters for SO_2 for Use with Eqs. (11)–(14), As Determined with a Mixture of Line-by-Line and Measured Transmittance Spectra of 20-cm^{-1} Resolution

WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'	WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'	WAVENUMBER (CM^{-1})	SPECTRAL PARAMETER C'
1215	-0.699	1355	1.127	2440	-4.854
1220	-0.782	1360	1.130	2445	-4.128
1225	-0.869	1365	1.124	2450	-2.992
1230	-0.963	1370	1.146	2455	-2.352
1235	-1.068	1375	1.105	2460	-1.890
1240	-1.196	1380	0.962	2465	-1.518
1245	-1.357	1385	0.711	2470	-1.230
1250	-1.566	1390	0.325	2475	-1.008
1255	-1.856	1395	-0.232	2480	-0.848
1260	-2.233	1400	-1.061	2485	-0.763
1265	-2.755	1405	-1.771	2490	-0.734
1270	-3.605	1410	-2.609	2495	-0.720
1275	-4.639	1415	-3.022	2500	-0.717
1280	-5.105	1420	-3.354	2505	-0.710
1285	-4.672	1425	-3.732	2510	-0.730
1290	-4.105	1430	-4.192	2515	-0.839
1295	-3.657	1435	-4.740	2520	-1.047
1300	-3.196	1440	-5.353	2525	-1.361
1305	-2.706	1445	-5.668	2530	-1.772
1310	-1.964	1450	-5.668	2535	-2.296
1315	-1.309	2400	-6.390	2540	-3.056
1320	-0.686	2405	-6.390	2545	-4.107
1325	-0.041	2410	-6.390	2550	-4.531
1330	0.368	2415	-6.390	2555	-4.940
1335	0.671	2420	-6.390	2560	-5.422
1340	0.903	2425	-6.390	2565	-6.018
1345	1.058	2430	-5.991	2570	-6.390
1350	1.114	2435	-5.327	2575	-6.390
				2580	-6.390

were recently made available in the literature,[5] as they were applied to nitrous oxide.

III. Application to SO_2

The parameters of the proposed band model for sulfur dioxide were determined through the use of a mixture of synthetic and measured spectra. The former transmittance data were generated with FASCODE 1C[23] and consisted of ten spectral curves for homogeneous paths within each of ten pressure levels of several standard atmospheric profiles.[24] Calculations of monochromatic transmittances are performed by this code through the use of Eq. (4), the classical line-broadening profiles, and the AFGL Line Parameters Compilation. The spectral degrading is accomplished through Eq. (3) in which use is made of a triangular filter function of 20-cm^{-1} full width at half-intensity. In the present effort these mean transmittance calculations were repeated at 5-cm^{-1} intervals throughout the bands of SO_2 in the infrared.

Prior to the model development, the line-by-line data were compared with the available measurements.

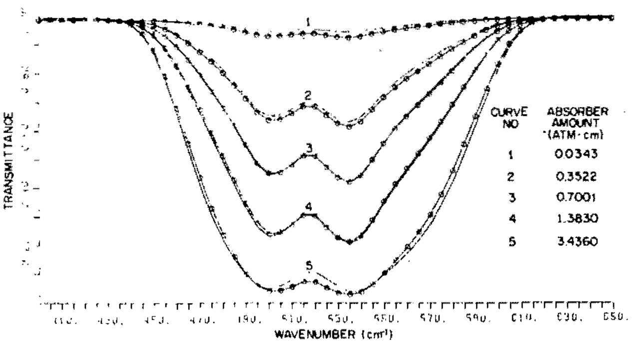

Fig. 1. Comparisons between line-by-line (unmarked) and model (O) calculated transmittances in the ν_2 band of SO_2 at a pressure of 0.887 atm, at a temperature of 281.6 K, and for the absorber amounts indicated in the figure.

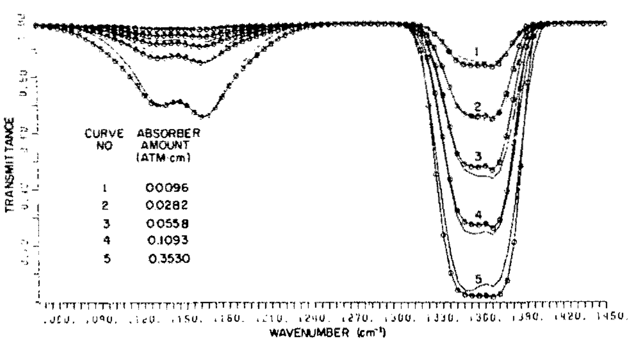

Fig. 2. Comparisons between line-by-line (Unmarked) and model (O) calculated transmittances in the ν_1 and ν_3 bands of SO_2 at a pressure of 0.5334 atm, at a temperature of 255.1 K, and for the absorber amounts indicated in the figure.

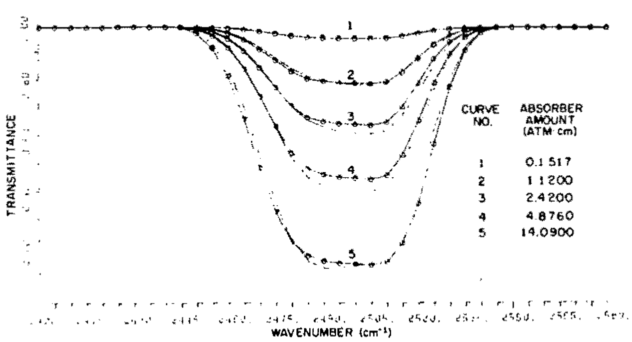

Fig. 3. Comparisons between line-by-line (unmarked) and model (O) calculated transmittances in the $\nu_1 + \nu_3$ band of SO_2 at a pressure of 0.3040 atm, at a temperature of 229.7 K, and for the absorber amounts indicated in the figure.

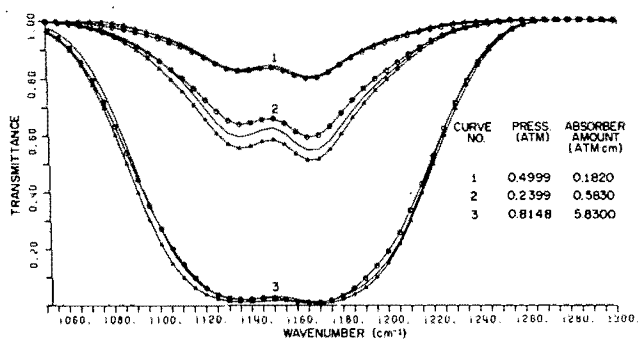

Fig. 4. Comparisons between line-by-line (unmarked), model (O), and measured[6] (Δ) transmittances in the ν_1 band of SO_2 at a temperature of 298 K and the conditions lised in the figure.

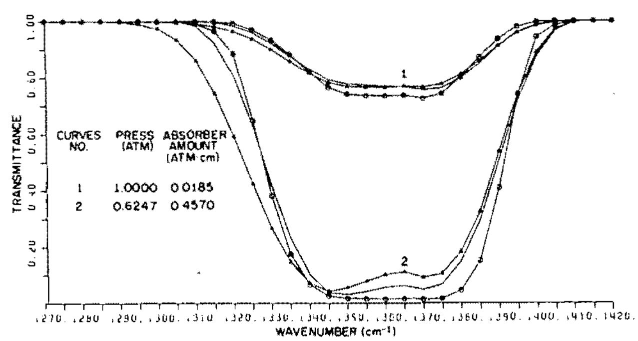

Fig. 5. Comparisons between line-by-line (unmarked), model (O), and measured[6] (Δ) transmittances in the ν_3 band of SO_2 at 296 K and the conditions listed in the figure.

Laboratory spectra for SO_2 by Burch *et al.*[6] were made available by AFGL in tape form. The measurements extend primarily from 991 to 1446 cm^{-1} and cover the ν_1 and ν_3 absorption bands. The data set contains forty-six samples at a resolution of $\sim$1 cm^{-1} varying in temperature from 296 to 575 K, in pressure from 0.05 to 15.8 atm, and in absorber amount from 0.018 to 5.91 atm cm. Only the samples at temperatures <298 K, pressures below 1 atm, and absorber amounts <5.86 atm cm were selected for the analysis reported here. The measured transmittances were degraded to the same resolution as the calculations, and equivalent pressures were determined through the use of the relation

$$P = (B - 1)p + P_T, \tag{16}$$

where P is the equivalent (total) air pressure, B is a constant representing the ratio of the self-broadening ability of SO_2 to the broadening ability of N_2, p is the SO_2 partial pressure in the absorption cell, and P_T is the total gaseous pressure of the gas mixture. A value for B of 4.0 was adopted[6] in this equation.

For the purpose of strengthening the validity of the model development for SO_2, both the line-by-line and the measured transmittance data were incorporated in the minimization procedure dictated by Eqs. (14) and (15). The absorber and the spectral parameters were determined simultaneously for all the four spectral regions combined. The values for the resulting absorber parameters a, n, and m were 0.8466, 0.2135, and 0.0733, respectively. A listing of the spectral parameters at 5-cm^{-1} intervals throughout the bands is provided in Tables I and II. Figures 1–3 show a comparison between the line-by-line developing data and the model calculations. Figures 4 and 5 compare the model with the line-by-line and the measurements. Although reasonable agreement is observed in these figures, Fig. 5 shows that the line-by-line and the measurements disagree noticeably near the edge of the band. Since the proposed band model was developed using the

Table III. Average Vertical Concentration Profile for Atmospheric SO_2 As Modified from Ref. 26 for Use with Proposed Band Model

HEIGHT (KM)	MIXING RATIO (PPMV)	HEIGHT (KM)	MIXING RATIO (PPMV)
0	0.30E-03	17	0.55E-04
1	0.27E-03	18	0.50E-04
2	0.25E-03	19	0.41E-04
3	0.20E-03	20	0.31E-04
4	0.14E-03	21	0.26E-04
5	0.12E-03	22	0.22E-04
6	0.95E-04	23	0.20E-04
7	0.83E-04	24	0.19E-04
8	0.70E-04	25	0.18E-04
9	0.65E-04	30	0.13E-04
10	0.60E-04	35	0.11E-04
11	0.58E-04	40	0.13E-04
12	0.55E-04	45	0.20E-04
13	0.56E-04	50	0.35E-04
14	0.56E-04	70	0.35E-04
15	0.58E-04	100	0.35E-04
16	0.60E-04	>100	0.35E-04

mixture of transmittance data for the four bands combined, this disagreement affected the overall accuracy of the model. The overall rms error was found to be 2.37%. When the measured data were excluded in the minimization, the error dropped to 0.96%.

The parameters of the proposed model were determined in the form presented for easy adaptability with the LOWTRAN code.[25] A diurnally and seasonally averaged mixing ratio profile[26] for SO_2 is shown in Table III, which may be useful for slant path calculations through the thirty-three-layer standard atmosphere models. Along any one of the layers the absorber amount is given by

$$U(\text{atm cm}) = 0.7732 \times 10^{-4} \text{ ppmv } \rho_a(g/m^3)Z(km), \qquad (17)$$

where ppmv is the absorber concentration in parts per million by volume, and ρ_a is the air density. It is to be noted, however, that the use of the proposed model and mixing ratio profile on a vertical path through the entire atmosphere would not show any significant amount of absorption. The model is of far greater value in applications to polluted environments, in which cases it is not unusual to encounter values for the mixing ratios over a 1000 times larger than those on the profile provided. The LOWTRAN code could still be valuable with the band model in it if it is run on mode MODEL 7, which involves the inclusion of vertical profiles by the user.

In the interest of illustrating the use of the equations and parameters provided in the present work, consider a 100-km horizontal path at 2-km altitude in the U.S. Standard Atmosphere (P = 795 mbar, T = 275.1 K, and $\rho_a = 7.364 \times 10^2$ g/m^3). Assuming a polluted environment with a SO_2 concentration of 30×10^{-3} ppmv, Eq. (17) gives

$$U = 0.7732 \times 10^{-4} \times 30 \times 10^{-4} \times 7.364 \times 10^2 \times 100$$
$$= 0.1708 \text{ atm cm}.$$

According to Eq. (13) the equivalent absorber amount is

$$W = \left(\frac{795.0}{1013.0}\right)^{0.2135} \left(\frac{273.15}{275.1}\right)^{0.0733} \times 0.1708$$
$$= 0.1621 \text{ atm cm}.$$

At a wave number of 530 cm^{-1}, Table I gives a C' value of 0.0470, such that X in Eq. (11) yields

$$X = 0.0470 + \log_{10}(0.1621) = -0.7432.$$

The transmittance for these conditions follows from Eq. (14) as

$$\tau = \exp[-10^{0.8466(-0.7432)}] = 0.7907.$$

IV. Discussion and Conclusions

A band model has been presented for the calculation of atmospheric SO_2 molecular transmittance of 20-cm^{-1} resolution, at 5-cm^{-1} intervals throughout four infrared bands extended from 400 to 650, 1050 to 1450, and 2400 to 2580 cm^{-1}. A well-established double-exponential function was assumed, in connection with a recently developed numerical procedure, for determining three absorber parameters and a single spectral parameter at 5-cm^{-1} intervals. The resulting model is LOWTRAN compatible. A mixture of line-by-line data computed with FASCODE 1C and laboratory measurements by Burch *et al.* was used in the model development. An average vertical concentration profile of SO_2 is proposed for use with the standard atmospheres. The model reproduces the developing data throughout all the bands within an average rms error of 2.37%.

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Molecular transmittance band model for ammonia

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A validated band model for atmospheric ammonia in the spectral region from 600 to 1960 cm^{-1} (5.10–16.67 μm) is presented. An exponential transmission function parameter is provided at 5-cm^{-1} intervals for 20-cm^{-1} spectral resolution transmittance calculations. A vertical profile of the ammonia volume mixing ratio is also proposed for use with the 33-layer standard atmospheres.

Ammonia (NH_3) was first identified as an atmospheric gaseous constituent[1] through the study of ammonium containing aerosol particles in precipitation water. Considerable evidence[2] suggests that a major part of atmospheric NH_3 is of biospheric origin as a result of the decomposition of nitrogeneous organic matter in aquatic and terrestrial ecosystems. Its near-IR spectrum consists of three major absorption regions[3]: (1) the 950-cm^{-1} region due primarily to the fundamental ν_2 band but overlapped at low frequencies by the combination $2\nu_2$-ν_2 band; (2) the 1828-cm^{-1} region due primarily to the fundamental ν_4 band but overlapped at low frequencies by the ν_2 band and at high frequencies by the $2\nu_2$ band; (3) the 3300-cm^{-1} region associated with the ν_1, ν_3, and $2\nu_4$ bands. Normally, the first two absorption regions are considered sufficiently intense to warrant their development into band models.

In an earlier publication[4] use was made of an analytical function together with a numerical procedure for parametrization to develop a band model for atmospheric NH_3. A double exponential function was adopted, as described by four absorber dependent and a single spectral parameter, determined at successive intervals within the absorption region. The modeling procedure involved the nonlinear determination of the absorber parameters using strictly line-by-line calculated transmittance data for only four spectral intervals within the 690–1230-cm^{-1} region (i.e., the ν_2 band). The spectral locations of these intervals were chosen by trial and error depending on the minimization of the deviation between the transmittance data and the model calculations at the same conditions of the data. The remaining spectral parameters were then individually obtained through use of the absorber parameters already available and averages of the transmittance data at each spectral interval.

The work presented here represents a substantial revision of the earlier effort on the modeling of NH_3. The principal revisions are as follows: (1) the transmission function was simplified to one with three absorber-type parameters and one spectral parameter; (2) the parametrization procedure procedure was replaced with a more recent version which optimizes all the model parameters simultaneously[5]; (3) the transmittance averages used as data in the modeling were calculated with an updated version of FASCODE,[6] validated with laboratory measurements,[7] and also extended at 5-cm^{-1} intervals to the 600–1960-cm^{-1} spectral region (thus adding the ν_4 band); (4) an average vertical mixing ratio profile for NH_3 in the atmosphere is provided with the proposed band model.

A mathematically simple, computationally fast, and accurate function representing the average transmittance τ over a broad spectral interval that was adopted earlier may be slightly modified to the form

$$\tau = \exp(-10^{aX}), \tag{1}$$

with

$$X = C' + \log_{10} W, \tag{2}$$

$$W = (P/P_0)^n (T_0/T)^m U. \tag{3}$$

Here a, n, and m are absorber parameters, C' is a spectral parameter, U is the absorber amount, W is the equivalent absorber amount, P and T are, respectively, the pressure and temperature, P_0 = 1013.25 mbar, and T_0 = 273.16 K. Letting

$$C' = \log_{10} C, \tag{4}$$

in Eq. (2), Eq. (1) may be more compactly expressed as

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Table I. Spectral Parameter C' for Ammonia to be used with Eqs. (1)-(6) in the Calculation of 20-cm^{-1} Resolution Atmospheric Transmittance

WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'
600	-4.0686	825	-0.8568	1050	-0.6079
605	-3.8623	830	-0.8713	1055	-0.6272
610	-3.3984	835	-0.8984	1060	-0.6304
615	-2.8857	840	-0.9076	1065	-0.6193
620	-2.5814	845	-0.9024	1070	-0.6026
625	-2.4066	850	-0.8882	1075	-0.5882
630	-2.3850	855	-0.8968	1080	-0.6029
635	-2.5415	860	-0.9492	1085	-0.6317
640	-2.8161	865	-1.0089	1090	-0.6862
645	-3.2265	870	-1.0846	1095	-0.7447
650	-3.7177	875	-1.1556	1100	-0.7921
655	-3.9932	880	-1.1792	1105	-0.8275
660	-4.0683	885	-1.1946	1110	-0.8595
665	-4.0785	890	-1.1964	1115	-0.8856
670	-3.9912	895	-1.2173	1120	-0.9236
675	-3.7418	900	-1.2424	1125	-0.9934
680	-3.4742	905	-1.1744	1130	-1.0693
685	-3.2651	910	-0.9743	1135	-1.1460
690	-3.0715	915	-0.6350	1140	-1.2100
695	-2.9500	920	-0.2975	1145	-1.2863
700	-2.8669	925	-0.0705	1150	-1.3593
705	-2.7723	930	0.0144	1155	-1.4292
710	-2.6614	935	-0.0978	1160	-1.5029
715	-2.5613	940	-0.3536	1165	-1.6054
720	-2.4372	945	-0.5630	1170	-1.7067
725	-2.3085	950	-0.5479	1175	-1.8110
730	-2.1696	955	-0.3784	1180	-1.9350
735	-2.0302	960	-0.1797	1185	-2.0346
740	-1.9166	965	-0.1151	1190	-2.1305
745	-1.8071	970	-0.3085	1195	-2.2294
750	-1.7221	975	-0.6180	1200	-2.3724
755	-1.6370	980	-0.9718	1205	-2.4917
760	-1.5453	985	-1.2926	1210	-2.6218
765	-1.4487	990	-1.2748	1215	-2.8056
770	-1.3539	995	-1.1217	1220	-2.9693
775	-1.2570	1000	-1.0197	1225	-3.1101
780	-1.1618	1005	-0.9300	1230	-3.2790
785	-1.1131	1010	-0.8817	1235	-3.5315
790	-1.0324	1015	-0.8723	1240	-3.7011
795	-1.0559	1020	-0.8309	1245	-3.8952
800	-1.0190	1025	-0.7804	1250	-4.1527
805	-0.9721	1030	-0.7075	1255	-4.4121
810	-0.9218	1035	-0.6431	1260	-4.5244
815	-0.8680	1040	-0.6176	1265	-4.8599
820	-0.8556	1045	-0.6012	1270	-5.1940

Table II. Spectral Parameter C' for Ammonia to be used with Eqs. (1)-(6) in the Calculation of 20-cm^{-1} Resolution Atmospheric Transmittance

WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'
1275	-5.5589	1505	-1.4492	1735	-0.9706
1280	-5.8170	1510	-1.3730	1740	-0.9569
1285	-7.6686	1515	-1.2859	1745	-0.9928
1290	-10.0000	1520	-1.2554	1750	-1.0310
1295	-10.0000	1525	-1.2129	1755	-1.0767
1300	-10.0000	1530	-1.1689	1760	-1.1053
1305	-10.0000	1535	-1.1802	1765	-1.1241
1310	-10.0000	1540	-1.1948	1770	-1.1717
1315	-10.0000	1545	-1.1882	1775	-1.2203
1320	-10.0000	1550	-1.2185	1780	-1.2772
1325	-8.4265	1555	-1.2464	1785	-1.3356
1330	-10.0000	1560	-1.2522	1790	-1.3855
1335	-7.3660	1565	-1.2946	1795	-1.4734
1340	-7.4862	1570	-1.3587	1800	-1.5701
1345	-6.8246	1575	-1.3971	1805	-1.6572
1350	-6.6102	1580	-1.4488	1810	-1.7638
1355	-6.3264	1585	-1.5261	1815	-1.8652
1360	-6.0751	1590	-1.5495	1820	-1.9919
1365	-5.8304	1595	-1.5478	1825	-2.1449
1370	-5.5963	1600	-1.4926	1830	-2.2388
1375	-5.3863	1605	-1.3115	1835	-2.3251
1380	-5.2319	1610	-1.0455	1840	-2.3936
1385	-5.0536	1615	-0.7987	1845	-2.4525
1390	-4.9029	1620	-0.5972	1850	-2.5998
1395	-4.7789	1625	-0.4664	1855	-2.7147
1400	-4.5867	1630	-0.4244	1860	-2.7704
1405	-4.3414	1635	-0.4426	1865	-2.7852
1410	-4.1399	1640	-0.4952	1870	-2.7524
1415	-3.9764	1645	-0.5772	1875	-2.7646
1420	-3.7553	1650	-0.6845	1880	-2.8507
1425	-3.5773	1655	-0.8097	1885	-3.0422
1430	-3.4123	1660	-0.9443	1890	-3.2642
1435	-3.2254	1665	-1.0904	1895	-3.5201
1440	-3.0384	1670	-1.2232	1900	-3.7771
1445	-2.9243	1675	-1.2853	1905	-3.9302
1450	-2.7755	1680	-1.2949	1910	-4.1125
1455	-2.5809	1685	-1.2708	1915	-4.3079
1460	-2.4726	1690	-1.1896	1920	-4.4572
1465	-2.3206	1695	-1.1467	1925	-4.5387
1470	-2.1209	1700	-1.1187	1930	-4.5772
1475	-2.0331	1705	-1.0700	1935	-4.6061
1480	-1.9016	1710	-1.0392	1940	-4.4832
1485	-1.7458	1715	-1.0227	1945	-4.2924
1490	-1.6927	1720	-1.0176	1950	-4.1789
1495	-1.5958	1725	-1.0089	1955	-4.0360
1500	-1.4863	1730	-1.0021	1960	-4.0335

$$\tau = \exp\{-(CW)^a\}. \tag{5}$$

Equation (5) is appealing for use as a transmission function because it is analytically simple and asymptotic to one and zero, respectively, as the argument ranges from zero to infinity. It was used earlier[8] in curve-fitting to the empirical transmission tables in LOWTRAN[9] for water vapor, uniformly mixed gases, and ozone. More recently, it was adopted in an extensive development effort[10] leading to individual models for the uniformly mixed and trace gases. Although not much physical significance may be attributed to this function, it has been shown[11] that in some cases empirical approximations have outperformed theoretically based band models such as the regular[12] and the random.[13] It does not approach the functional form of any of such classical models in either the limiting weak-line or strong-line conditions (i.e., U/P very small or very large, respectively). It has been shown[14] that it leads to a transmittance polynomial proposed earlier[15] for use with water vapor and carbon dioxide, which, in turn, originated as an approximation to the strong-line limit to the random model. The classical models were derived mostly for homogeneous paths, specific absorption line configurations, and Lorentzian broadening conditions. Equation (5) is generally proposed for use along inhomogeneous paths, for nonspecific absorption line configurations, and for combinations of Lorentzian and Doppler broadening conditions.

In atmospheric applications the absorber amount U may be computed from the definition $U = \rho_g Z$, where ρ_g is the absorber density and Z is the path length. In atmospheric centimeters (atm cm), it becomes

$$U = 0.7732 \times 10^{-4} M \rho_a Z, \tag{6}$$

where M is the absorber concentration in parts per million by volume, ρ_a is the air density in grams per meter cube, and Z is expressed in kilometers. The model parameters a, n, and m for the absorption regions and the C' for each spectral interval within such regions may be determined from minimization of the square error ϵ given by

$$\epsilon = \sum_i \sum_j [\tau(i,j) - \tau_M(i,j)]^2, \tag{7}$$

where $\tau(i,j)$ is a transmittance datum, τ_M is defined by either Eq. (1) or (5), $i = 1,2, \ldots, I$ is the number of spectral intervals, and $j = 1,2, \ldots, J$ is the number of data values.

DEPARTMENT OF THE AIR FORCE
AIR FORCE GEOPHYSICS LABORATORY (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731-5000

REPLY TO ATTN OF: OPI/S. A. Clough — 1 May 1987

SUBJECT: Errors in FASCOD2

TO: FASCOD2 Users

Dear Colleague:

A serious error has been discovered in the implementation of the nitrogen continuuum in FASCOD2. This error gives incorrect optical depths in the spectral region from 2385 cm-1 to 2500 cm-1 for all versions of FASCOD2. The lines flagged with a ? in the following list will correct this error as well as an error in the temperature correction for the diffuse ozone.

```
C********     NITROGEN    ********                                            500820
C                                                                             500830
C  THE NITROGEN CONTINUUM IS IN UNITS OF (CM**2/MOL)*(1/CM-1)*(CM/KM)       ?500840
C                                                                            ?500845
      UNITN2=1.0E-05                                                          500850
      IF(NMOL.GE.22) THEN                                                     500860
         WN2=WK(22)                                                           500870
      ELSE                                                                    500880
         WN2=WBROAD                                                          ?500890
      ENDIF                                                                   500900
      WXN2 =( WN2 )    * RHOAVE * UNITN2                                      500910
C                                                                             500920
      CALL N2CONT(V1C,V2C,DVC,NPTC,CN2T0)                                     500930

C********     DIFFUSE OZONE   ********                                        501020
C                                                                             501030

               DO 135 J=1,NPTO3                                               501220
               C(J)=C0(J)*WO3                                                 501230
C                                                                            ?501240
               VJ=V1C +DVC *FLOAT(J-1)                                        501250
               IF(JRAD .EQ. 1) C(J) =C(J) *RADFN(VJ,XKT,V1TST)                501260
               C(J)=C(J)*(1.+CT1(J)*TC+CT2(J)*TC*TC)                         ?501270
135            CONTINUE                                                       501280

     C         '0***************',10X, 'CORRECTED 1 MAY 87 ' )              ?501505
      END                                                                     501510


      BLOCK DATA BN2                                                        > 519160
C>    BLOCK DATA                                                            > 519170
C[    IMPLICIT DOUBLE PRECISION (V)                                         [ 519180
C                                                                             519190
C           UNITS OF (CM**2/MOL)*(1/CM-1)*(CM/KM)                            ?519200
C                                                                            ?519205
```

Shepard A. Clough

Shepard A. Clough
Infrared Physics Branch
Optical Physics Division

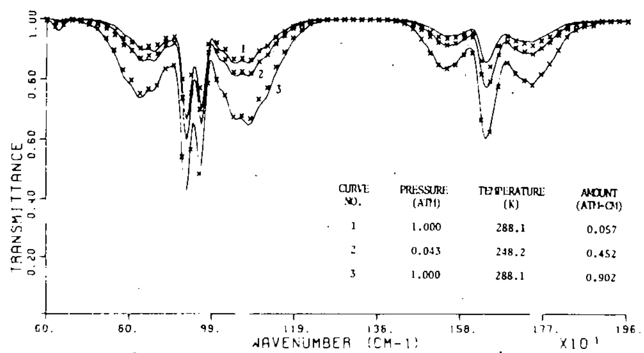

Fig. 1. Transmittance comparison between the proposed band model for ammonia (×) and line-by-line spectra used in the development (−) for various atmospheric conditions.

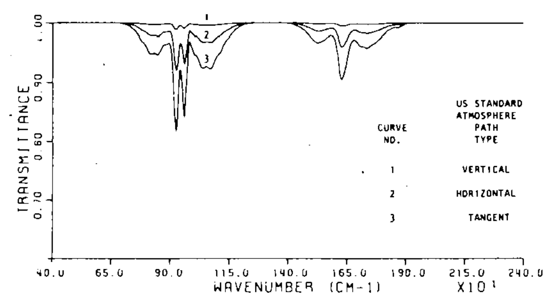

Fig. 2. Transmittance calculations for ammonia using the proposed model and vertical concentration profile as incorporated into LOWTRAN 6 for (1) a vertical path from sea level to the top of the atmosphere; (2) a 100-km horizontal path at sea level; (3) a path tangent to earth's surface and extending from one end of the atmosphere to the other.

In the present modeling of NH_3 transmittance, the parameter set a, n, and m, and the spectral parameter C' at 5-cm^{-1} intervals were obtained with the use of Eqs. (1)–(7). The transmittance data were generated with FASCOD 1C and consisted of 20-cm^{-1} resolution averages repeated at 5 cm^{-1} throughout the absorption bands, for homogeneous paths at the conditions of ten pressure levels within five of the standard atmosphere models.[16] In the generation of the transmittance data use was made of a triangular filter function of 20-cm^{-1} full width at half-intensity. To extend the applicable range of the model to polluted environments, the path length at each pressure level was increased to include absorber amounts of the order of 100× the amount found in a vertical path from sea level to the atmospheric top at 100-km altitude. Special transmittance calculations were also performed at the conditions of available measurements[7] in the ν_2 region to validate the synthetic spectra with measured laboratory data. The resulting values of the absorber parameters are $a = 0.6035$, $n = 0.6968$, and $m = 0.3377$, while the values of the spectral parameters are listed in Tables I and II. It is noted that this parameter set supersedes the set published in Ref. 10. The model reproduced the original data used in its development within a mean rms deviation of 0.95%. Figure 1 depicts spectral curves comparing model calculations to representative 20-

Table III. Average Vertical Concentration Profile for Atmospheric Ammonia as Modified from Ref. 19 for use with the Proposed Band Model

HEIGHT (KM)	MIXING RATIO (PPMV)	HEIGHT (KM)	MIXING RATIO (PPMV)
0	0.130E-02	17	0.550E-04
1	0.125E-02	18	0.100E-04
2	0.120E-02	19	0.550E-05
3	0.110E-02	20	0.100E-05
4	0.100E-02	21	0.550E-06
5	0.925E-03	22	0.100E-06
6	0.850E-03	23	0.100E-06
7	0.775E-03	24	0.100E-06
8	0.700E-03	25	0.100E-06
9	0.625E-03	30	0.100E-06
10	0.550E-03	35	0.100E-06
11	0.475E-03	40	0.100E-06
12	0.400E-03	45	0.100E-06
13	0.350E-03	50	0.100E-06
14	0.300E-03	70	0.100E-06
15	0.200E-03	100	0.100E-06
16	0.100E-03	>100	0.100E-06

cm^{-1} degraded line-by-line spectra for the ν_2 and ν_4 regions together, which were used in the model development.

Shown in Fig. 2 are transmittance calculations obtained from the proposed model after its incorporation into LOWTRAN 6. The calculations were made assuming the vertical ammonia concentration profile of Table III together with the U.S. Standard Atmosphere model. In this figure, curve 1 represents the transmittance for a vertical inhomogeneous path from sea level to the top of the atmosphere. Curve 2 represents a 100-km horizontal homogeneous path at sea level altitude and atmospheric conditions. This curve is valuable, for example, in showing the transmittance spectra for a 1-km, sea level, horizontal path in a polluted environment having an ammonia concentration 100× higher than the value given in Table III. Curve 3 represents an inhomogeneous path tangent to the earth's surface and extending in both directions from one end of the atmosphere to the other. This curve illustrates the transmittance spectra along the path originally chosen as a guide by AFGL in the selection of absorption lines for inclusion in the line parameter compilations.[17,18] Table III provides a diurnally and seasonally averaged vertical concentration profile of ammonia, as modified from the one proposed by Smith[19] to accommodate the thirty-three atmospheric levels used in LOWTRAN.

The authors express their thanks to the Air Force Geophysics Laboratory at Hanscom Air Force Base, Bedford, MA, for providing the funds to support the work reported here.

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Validated infrared transmittance band model for methane in the atmosphere: corrigenda

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0003-6935/85/121729-02$02.00/0.

In a recent paper[1] on development and validation of a molecular transmittance band model for atmospheric methane (CH_4), one of the three significant IR bands (from 4105 to 4730 cm^{-1}) was unintentionally ignored, and an error in the vertical concentration profile was accidentally introduced. The purpose of this Letter is to make the necessary corrections and provide illustrative transmittance spectra for this band. These corrections are deemed important because methane forms part of the group of five gases originally modeled in LOWTRAN as a single model for the so-called uniformly-mixed gases.

In the earlier cited reference use was made of a double exponential transmission function together with nonlinear optimization techniques to develop a band model for the methane bands from 1085 to 1755 cm^{-1} and from 2370 to 3215 cm^{-1}. The data consisted of line-by-line calculations computed using FASCOD1C[2] and of laboratory measurements made by Gryvnak *et al.*[3] The model parameters were determined at 5 cm^{-1} for the 20-cm^{-1} spectral resolution for LOWTRAN.[4] Since there were no laboratory measurements for the band being presented here, its modeling was done using the same transmission function and numerical methods used with the other bands but with degraded line-by-line data only.

Briefly stated, the band model is given by

$$\tau = \exp\{-10^{a}[C_i'(\Delta\nu) + \log W]\} \tag{1}$$

with

$$W = \left(\frac{P}{P_o}\right)^n \left(\frac{T_o}{T}\right)^m U, \tag{2}$$

$$U = 0.7732 \times 10^{-4} M \rho_a z, \tag{3}$$

where a, n, and m are absorber-type parameters, $C_i'(\Delta\nu)$, $i = 1,2, \ldots I$, is a spectral parameter, I is the number of spectral intervals, P is the total atmospheric pressure, T is the atmospheric temperature, U (atm cm) is the absorber amount, M (ppmv) is the absorber concentration in parts per million by volume, ρ_a (g/m^3) is the air density, Z (km) is the path length, and the subscript o represents standard temperature and pressure (STP) conditions. In the determination of the $C_i'(\Delta\nu)$ parameters listed in Table I, use was made of the absorber parameter obtained from the model development of the two earlier bands, i.e., $a = 0.5845$, $n = 0.7140$, and $m = 0.4186$. The resulting $C_i'(\Delta\nu)$ value at 5-cm^{-1} intervals are given in Table I. An overall rms transmittance deviation of

Table I. Spectral Parameter for Methane to be Used with Eqs. (1)–(3) for the Calculation of 20-cm^{-1} Resolution Transmittance Supplementing the Band Model in Ref. 1

WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'	WAVE-NUMBER (CM^{-1})	C'
4105	-8.7367	4255	-1.3642	4425	-1.9451	4585	-3.6245
4110	-10.0000	4270	-1.4016	4430	-1.9924	4590	-3.4791
4115	-7.4757	4275	-1.4713	4435	-2.0321	4595	-3.4710
4120	-5.1602	4280	-1.5836	4440	-2.0816	4600	-3.4210
4125	-4.2454	4285	-1.6984	4445	-2.1026	4605	-3.4125
4130	-3.7640	4290	-1.8085	4450	-2.1137	4610	-3.4475
4135	-3.3256	4295	-1.8486	4455	-2.1351	4615	-3.4140
4140	-3.0103	4300	-1.7464	4460	-2.1629	4620	-3.4908
4145	-2.7726	4305	-1.6338	4465	-2.1876	4625	-3.5164
4150	-2.5510	4310	-1.5555	4470	-2.2340	4630	-3.5944
4155	-2.3849	4315	-1.5552	4475	-2.2960	4635	-3.7403
4160	-2.2318	4320	-1.6935	4480	-2.3747	4640	-3.8192
4165	-2.1080	4325	-1.8165	4485	-2.4970	4645	-4.0177
4170	-2.0086	4330	-1.8417	4490	-2.6244	4650	-4.1833
4175	-1.9290	4335	-1.7697	4495	-2.7641	4655	-4.3518
4180	-1.8902	4340	-1.6346	4500	-2.8912	4660	-4.6486
4185	-1.8750	4345	-1.5589	4505	-3.0328	4665	-4.8778
4190	-1.8700	4350	-1.5466	4510	-3.1944	4670	-5.2542
4195	-1.8476	4355	-1.5604	4515	-3.3877	4675	-5.7834
4200	-1.7390	4360	-1.6307	4520	-3.4566	4680	-6.3451
4205	-1.5724	4365	-1.6867	4525	-3.1662	4685	-7.7212
4210	-1.4284	4370	-1.7593	4530	-2.7253	4690	-10.0000
4215	-1.3425	4375	-1.8051	4535	-2.3992	4695	-10.0000
4220	-1.3791	4380	-1.8167	4540	-2.2214	4700	-10.0000
4225	-1.5132	4385	-1.8518	4545	-2.2022	4705	-10.0000
4230	-1.6508	4390	-1.8559	4550	-2.3978	4710	-10.0000
4235	-1.7283	4395	-1.8547	4555	-2.7449	4715	-10.0000
4240	-1.6684	4400	-1.8907	4560	-3.2639	4720	-7.7337
4245	-1.5432	4405	-1.8851	4565	-3.9311	4725	-7.9729
4250	-1.4447	4410	-1.8933	4570	-4.1470	4730	-7.7973
4255	-1.3773	4415	-1.9081	4575	-3.9351		
4260	-1.3490	4420	-1.9025	4580	-3.7471		

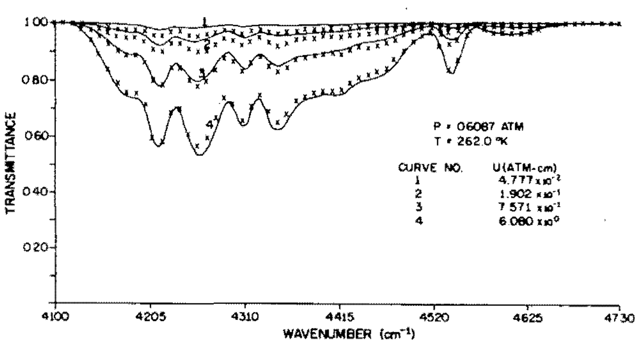

Fig. 1. Transmittance comparison between line-by-line (−) data degraded to 20 cm^{-1} and the proposed methane band model (X) for various absorber amounts.

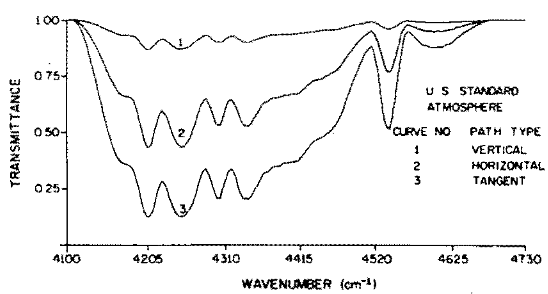

Fig. 2. Transmittance calculations for methane using a proposed model and vertical concentration profile as incorporated into LOWTRAN 6 for (1) a vertical path from sea level to the top of the atmosphere; (2) 100-km horizontal path at sea level; and (3) path tangent to earth's surface and extending from one end of the atmosphere to the other.

1.45% was obtained between the line-by-line data and the calculations made with the development model.

Shown in Fig. 1 are spectral curves comparing model calculations as well as the 20-cm^{-1} degraded line-by-line spectra from FASCOD1C used in the model development for the third band of methane. Figure 2 depicts transmittance calculations obtained from the proposed model after its incorporation into LOWTRAN 6. The calculations were made assuming the vertical methane concentration profile of Table II together with the U.S. Standard Atmosphere. In this figure, curve 1 represents the transmittance for a vertical inhomogeneous path from sea level to the top of the atmosphere at 100-km altitude. Curve 2 represents a 100-km horizontal homogeneous path at sea level altitude and atmospheric conditions. This curve is of value, for example, in showing the transmittance spectra for a 1-km, sea level horizontal path in a polluted environment with a methane concentration 100 times higher than the value given in Table II. Curve 3 represents an inhomogeneous path tangent to the earth's surface and extending in both directions from one end of the atmosphere (altitude of 100 km) to the other. This curve illustrates the

Table II. Average Vertical Concentration Profile for Atmospheric Methane as Modified from Ref. 7 for Use with a Proposed Band Model and Correcting an Error in Ref. 1

ALTITUDE (KM)	MIXING RATIO (PPMV)	ALTITUDE (KM)	MIXING RATIO (PPMV)
0	1.70	17	1.45
1	1.70	18	1.40
2	1.70	19	1.35
3	1.70	20	1.30
4	1.70	21	1.20
5	1.70	22	1.10
6	1.70	23	1.05
7	1.65	23	1.00
8	1.65	25	0.97
9	1.65	30	0.80
10	1.65	35	0.62
11	1.65	40	0.40
12	1.65	45	0.23
13	1.55	50	0.10
14	1.50	70	0.10
15	1.50	100	0.10
16	1.50	>100	0.10

transmittance spectra along the path originally chosen as guide by AFGL in the selection of lines for inclusion in the line parameter compilations.[5,6] Table II provides a diurnally and seasonally averaged vertical concentration profile of methane, as corrected from the earlier referenced publication dealing with the other IR bands of methane.[1] The profile in this table is a modification of the one proposed by Smith,[7] as designed for use with the proposed model.

The authors thank the Air Force Geophysics Laboratory at Hanscom Air Force Base, Bedford, Mass., for providing the funds to support the work reported here.

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Molecular transmittance band model for oxygen in the infrared

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Molecular oxygen is one of the main constituents of the atmosphere and is second only to nitrogen in relative concentration near the earth's surface. Only a small percent of its present level may be explained by the photodissociation of water vapor in the prebiologic atmosphere. Substantial documentation in the literature[1] indicates that the major part of the level increase was due to photosynthetic activity of the biosphere. An assumption currently made[2] is that oxygen is uniformly mixed in the atmosphere with an average value of $\sim 2.09 \times 10^5$ ppmv. Its most significant infrared absorption band near 7874 cm^{-1} (1.27 μm) was first made readily apparent from measurements of the solar spectrum.[3] There is a much weaker, less important infrared band near 9369 cm^{-1} (1.07 μm). Although earlier studies[4] have dealt with modeling of the first of these bands independent of other absorbing gases, the widely used computer code LOWTRAN[5] combines at present oxygen and other uniformly mixed gases in a single-band model.

In this Letter use was made of an empirical expression with three absorber-type parameters, and a single spectral parameters, to represent the transmission function for each oxygen band individually. The parametrization involved a nonlinear numerical procedure which optimized all the parameters simultaneously. The transmittance data consisted of 20-cm^{-1} resolution averages, computed with FASCOD1C[6]

Table I. Spectral Parameter C′ for Oxygen to be Used with Eqs. (1)–(4) in the Calculation of 20-cm⁻¹ Resolution Atmospheric Transmittance in the Infrared.

WAVE-NUMBER (CM -1)	C′	WAVE-NUMBER (CM -1)	C′	WAVE-NUMBER (CM -1)	C′
7650	-13.9459	7885	-6.8055	9270	-12.5754
7655	-13.7692	7890	-6.9114	9275	-12.3930
7660	-11.5048	7895	-6.9936	9280	-12.1907
7665	-13.1422	7900	-7.0514	9285	-11.9948
7670	-11.3242	7905	-7.0597	9290	-11.7759
7675	-12.6658	7910	-7.0689	9295	-11.5926
7680	-12.3571	7915	-7.1242	9300	-11.4214
7685	-12.2428	7920	-7.2094	9305	-11.2493
7690	-11.5492	7925	-7.3265	9310	-11.1099
7695	-11.6427	7930	-7.4671	9315	-10.9477
7700	-11.5173	7935	-7.6326	9320	-10.8332
7705	-11.2136	7940	-7.8110	9325	-10.7321
7710	-11.1558	7945	-8.0096	9330	-10.6380
7715	-11.1196	7950	-8.2104	9335	-10.5725
7720	-10.8040	7955	-8.4036	9340	-10.4409
7725	-10.8539	7960	-8.5453	9345	-10.2013
7730	-10.5128	7965	-8.7252	9350	-9.8939
7735	-10.4522	7970	-8.8511	9355	-9.6546
7740	-10.4172	7975	-8.9427	9360	-9.5053
7745	-10.1823	7980	-9.0375	9365	-9.4638
7750	-10.1435	7985	-9.1229	9370	-9.5526
7755	-10.0030	7990	-9.2240	9375	-9.6558
7760	-9.8136	7995	-9.3241	9380	-9.7430
7765	-9.7772	8000	-9.4436	9385	-9.7359
7770	-9.5693	8005	-9.5715	9390	-9.7896
7775	-9.4595	8010	-9.6951	9395	-9.8323
7780	-9.3502	8015	-9.8408	9400	-9.9447
7785	-9.1411	8020	-9.9759	9405	-10.1221
7790	-9.0476	8025	-10.1489	9410	-10.3707
7795	-8.8623	8030	-10.3027	9415	-10.6623
7800	-8.7051	8035	-10.5179	9420	-10.9761
7805	-8.5818	8040	-10.7265	9425	-11.2271
7810	-8.4282	8045	-10.9737	9430	-11.4091
7815	-8.3271	8050	-11.2339	9435	-11.4921
7820	-8.1958	8055	-11.5552	9440	-11.6015
7825	-8.0338	8060	-11.9595	9445	-11.6945
7830	-7.9652	8065	-12.2435	9450	-11.8333
7835	-7.8371	8070	-12.6942	9455	-11.9985
7840	-7.7476	8075	-13.2011	9460	-12.1788
7845	-7.6431	8080	-13.3141	9465	-12.3822
7850	-7.5736	9235	-13.9216	9470	-12.6605
7855	-7.5149	9240	-13.7293	9475	-13.0796
7860	-7.4194	9245	-13.5370	9480	-13.3528
7865	-7.2088	9250	-13.3447	9485	-13.6463
7870	-7.0722	9255	-13.1523	9490	-13.9398
7875	-6.8315	9260	-12.9600		
7880	-6.7027	9265	-12.7677		

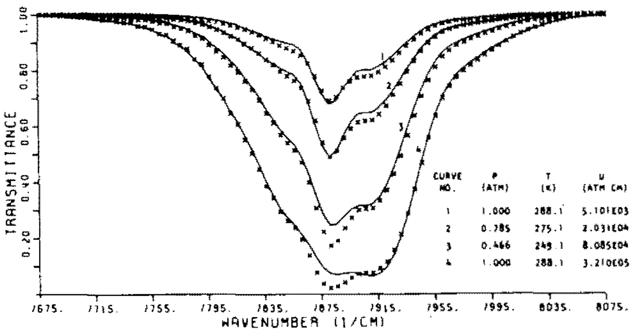

Fig. 1. Transmittance comparisons in the 7874-cm⁻¹ band of oxygen between the proposed model for oxygen (×), and line-by-line spectra used in the development of the model (−) for various atmospheric conditions.

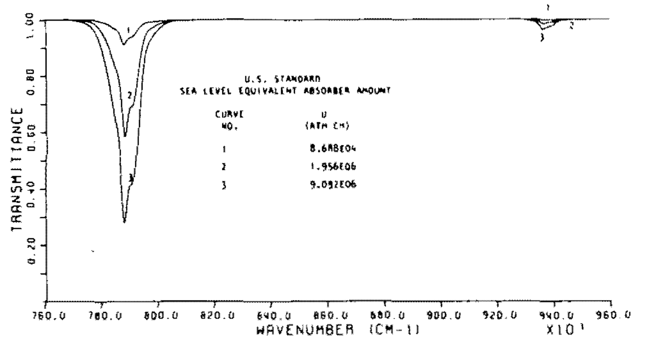

Fig. 2. Transmittance calculations for oxygen using the proposed band model with a vertical concentration of 2.09×10^5 ppmv as incorporated into LOWTRAN 6 for (1) a vertical path from sea level to the top of the atmosphere; (2) a 100-km horizontal path at sea level; and (3) a path tangent to the earth's surface and extending from one end of the atmosphere to the other.

and the Air Force line parameters[7] at ten pressure levels for several model atmospheres.[8] These were carried out at 5-cm⁻¹ spectral intervals throughout the two bands of oxygen, from 7650 to 8080 cm⁻¹ and from 9280 to 9480 cm⁻¹.

The molecular transmittance τ over a spectral interval within an absorption band of an atmosphere gas may be reasonably well approximated by the function[9]

$$\tau = \exp[-(CW)^a], \tag{1}$$

where

$$W = (P/P_o)^n\,(T_o/T)^m U, \tag{2}$$

$$C = 10^{C'}, \tag{3}$$

$$U = 0.7732 \times 10^4\, M\rho_a Z. \tag{4}$$

Here P (atm), T (K), M (ppmv), and ρ_a (g/m³) are, respectively, vertical profiles of pressure, temperature, absorber concentration, and air density, U (atm cm) is the absorber amount, Z (km) is the path length, and the subscript o denotes conditions at a standard temperature and pressure (namely, 1 atm and 273.16 K, respectively). Furthermore, the model in Eqs. (1)–(4) is defined by the absorber parameters set a, n, and m, and by a set of C' values for the spectral intervals within the absorption bands. In Eq. (3) C is redefined in terms of C' for computational convenience. The complete parameter set a, n, m, and C, $i = 1,2,\ldots,I$, for I spectral intervals, may be obtained from the equation[10]

$$\epsilon = \sum_i \sum_j [\tau(i,j) - \tau_m(i,j)]^2, \tag{5}$$

where ϵ is the least-squares error to be minimized using a standard method, such as the conjugate gradient descent, $J = 1,2,\ldots,J$ is an index for the data values, and the subscript m denotes the band model.

In the present modeling of the two oxygen bands use was made of τ_m in Eqs. (1)–(5), and of the data τ discussed above, to obtain the values $a = 0.5641$, $n = 0.9353$, $m = 0.1936$, and the values of C' listed in Table I. The developed model reproduced the original transmittance data used in the minimization within a spectral mean rms deviation of 1.37%. Figure 1 depicts spectral curves comparing model calculations with representative 20-cm⁻¹ degraded line-by-line spectra for the 7874-cm⁻¹ band.

Shown in Fig. 2 are transmittance calculations obtained from the proposed band model after its incorporation into LOWTRAN 6. They were made assuming an oxygen concentration of 2.09×10^5 ppmv, in combination with the U.S. Standard Atmosphere. In this figure, curve 1 represents the transmittance for a vertical inhomogeneous path from sea level to the top of the atmosphere at 100-km altitude. Curve 2 represents a 100-km horizontal homogeneous path at sea-level altitude and atmospheric conditions. This curve may be valuable, for example, in showing the transmittance spectra for a 10-km sea-level horizontal path in an environment having an oxygen concentration 10 times higher than the

assumed value. Curve 3 represents an inhomogeneous path tangent to the earth's surface and extending in both directions from one end of the atmosphere (100-km altitude) to the other. This curve illustrates the transmittance spectra along the path originally chosen as a guide by the Air Force Geophysics Laboratory in the selection of absorption lines for inclusion in their line parameter compilations.

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